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Shrimp and Redfish Studies; Bryan Mound Brine Disposal Site Off Freeport, Texas, 1979-1981.

VOL. III -SHRIMP SPAWNING SITE SURVEY

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Volume VI - SHRIMP BIOASSAYS

Work Unit 8 - Brine Toxicity and Avoidance/Attraction Bioassays on Shrimp

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ABSTRACT

In a study performed over October 1979-September 1980, immature brown shrimp were found to move through the nearshore marine environment in the vicinity of the brine diffuser offshore Freeport, Texas (and in the surrounding area) in two waves during summer as they emigrated from the estuaries to offshore spawning habitats. The major spawning habitat of brown shrimp is well offshore, generally located along the 40 to 50 m depth contours. White shrimp in the study area appeared mainly restricted to a band within about 8 km of the beach and spawning mainly occurred in these nearshore areas. The diffuser appears well-sited in terms of minimizing the impacts on spawning of these two shrimps--it is seaward of the area of greatest white shrimp activity and shoreward of the area of greatest brown shrimp activity.

Our data show a marked fall (August, September, October) spawning peak for brown shrimp and suggests that a spring peak may also be characteristic. White shrimp were found to spawn during summer periods, particularly June and July. Penaeid type eggs were seldom encountered in the samples; nauplii (Penaeidae) were abundant in the offshore block from June-September; protozoea (Penaeidae) were found abundant only during August at offshore stations (block A); mysis stage larvae (*Penaeus* spp.) were more abundant in August than in any other month when they were most abundant in block A; and *Penaeus* spp. postlarvae were well represented in all sampling areas, being most abundant in August.

Results of principal component and cluster analyses clearly separated block A sites from nearshore block B and C sites. Nearshore sites exhibited considerable overlap and no patterns were detected that could be related to white shrimp spawning areas. Results of multiple linear regression analyses showed the number of brown shrimp in spawning condition was greatly correlated with temperature and somewhat with levels of sterols in potential prey organisms. The number of white shrimp in spawning condition was strongly correlated with conductivity (salinity) and with four other variables, including in order of importance after conductivity, concentration of fatty acid 20:5 in the biota, temperature, dissolved oxygen and levels of sterols in the sediments.

The discriminant function analysis yielded a function that could discriminate with 100% success between sites in blocks B and C having or not having spawning white shrimp. The variables included in this function in order of their decreasing importance were sediment sterols, total organic carbon, biota carotenoids and mean particle size.

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We would like to express our gratitude to the captain and crew of the vessel *Tonya and Joe* for their patience and assistance during the 62 days spent at sea on this study, and for sharing with us their many years of experience in shrimp fishing. The logistical services of the Field Party Chiefs from the National Marine Fisheries Service were greatly appreciated, as was their assistance while at sea. Subcontractors Drs. B.S. Middleditch (University of Houston), J.M. Brooks, A.L. Lawrence and H.W. Armstrong (Texas A&M University) provided the analyses for biochemistry, sediment particle size and total organic carbon content, organ indices and histology, respectively. Dr. L.H. Pequegnat (Texas A&M University) provided taxonomic verifications of larval shrimp.

Mr. B.A. Adams and Mr. F.S. Lane deserve special recognition for their technical assistance both at sea and in the laboratory during what often turned out to be very long and tiring days. Mr. Adams also participated in most of the observational cruises and was at sea more than not during the summer of 1980.

Mr. Larry Martin served as Program Manager and his diligence in dealing with contractual matters and the scheduling of logistics and field work is gratefully appreciated. Data Management for the project was provided by W.B. Campbell and Scott Anderson, assisted by Alice Doerge, Cheryl Lewis and Brenda Hayes. Multivariate analyses were performed and interpreted by Declan Troy.

Particular thanks are due Jean Erwin who took personal charge of producing the many drafts of this report (some sections were revised almost daily until the deadline for submittal), including the final. Her good humor through the many revisions is appreciated as well as her efficient, and professional manner in producing the final draft. Bonnie Bower is acknowledged for drafting the figures used in this report.

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SECTION 1

INTRODUCTION

In 1975, the United States Congress passed the Energy Policy Conservation Act directing the Department of Energy (DOE) to develop the Strategic Petroleum Reserve (SPR) Program. The program produced a plan relying upon storage of oil underground. The underground caverns to be used for oil storage had been (or were to be) created by dissolving the interiors of coastal salt domes with raw water. One of several proposed SPR sites, Bryan Mound, is located near Freeport, Texas and served as subject of this study.

At Bryan Mound, the brine discharged will consist of that obtained from existing caverns as well as that from the leaching and filling of new caverns. Some oil is already being stored in the existing caverns at Bryan Mound. The displaced brine has either been sold or disposed of in injection wells. Once the intake-discharge facilities are completed, most, if not all of the brine will be disposed of offshore. Over a period of 66 months, as much as 684,000 barrels/day may be discharged from the Bryan Mound site (U.S. Department of Energy 1978).

Once the SPR sites were selected, site preparations and the normal Environmental Impact Statement (EIS) process began and resulted in the required draft and final EIS documents. Site-specific, environmental impact studies of offshore disposal of brine from the Bryan Mound site using a before disposal-after disposal approach were designed under the auspices of the DOE, and subsequently implemented by Texas A&M University (TAMU). These studies were initiated in September 1977 and are ongoing.

A discharge permit from the Environmental Protection Agency (EPA) was required before operations could begin. In their permit application, the DOE applied for a discharge location approximately five nautical mi offshore at the 50-ft depth contour. After reviewing the alternative disposal sites discussed in the draft EIS, the EPA disagreed with DOE as to an appropriate discharge site and recommended a site at the 70-ft depth contour located approximately 12.4 nautical miles offshore. A public hearing concerning the matter was held in Freeport, Texas, in May of 1978. Based upon information provided at the hearing and subsequent information provided from a number of sources, the EPA determined that carefully monitored brine disposal could be permitted for the 12-mi site. Factors which contributed to the unacceptability of the 5-mi site included unique habitat characteristics (rock-pile reefs, shell banks, coral head reefs, and liberty ship reefs); the 5 mi area generally represents good white shrimp (*Penaeus setiferus*) habitat and may be a white shrimp spawning site; both white and brown (*Penaeus aztecus*) shrimp known to migrate through the area and the effects of brine on the migration patterns are unknown; penaeid shrimp postlarvae (particularly brown shrimp) may overwinter in the sediments; redfish were thought to use the habitats represented at the 5-mi site for spawning; and, finally, commercial and sport fisheries were particularly active in the immediate vicinity of the 5-mi site during some seasons (Bob Vickery, Environmental Protection Agency, personal communication).

Some of the above concerns held true for the 12-mi site and disposal of brine at the 12-mi site may yet impact the 5-mi site. For example, a plume of water characterized by salinity 0.5 ‰ above ambient has been modeled by MIT to extend for some six to seven mi and thus, could influence of 5-mi site. Within the area in question, ambient bottom water salinity ranges from about 34 to 37 ‰, being lowest in spring and highest in winter (Metzbower et al. 1980).

In August 1979, the National Marine Fisheries Service (NMFS) awarded contracts to conduct pre- and post-discharge assessments of shrimp populations in relation to the Bryan Mound salt dome disposal site in the Gulf of Mexico 12.5 mi offshore from Freeport, Texas, and to determine the acute toxicity and avoidance/attraction responses of shrimp and redfish to Bryan Mound brine. To attain these goals, the contracted tasks included field and laboratory investigations and statistical analyses of data.

The general goals of Work Unit 5 were to identify brown and white shrimp spawning areas in the vicinity of the brine disposal site and the surrounding area, and to relate shrimp spawning areas to season, location and depth, hydrographic data, and sediment properties. The approach used in the program was to locate concentrations of shrimp systematically within the vicinity of the brine disposal site, determine the proportions of sexually mature females at or near spawning condition in these populations, and obtain synoptic samples of planktonic reproductive products (eggs, larvae, postlarvae) in the water column and at the bottom in the areas where sexually mature animals were found most abundant. Localities having either a high percentage of sexually mature female shrimp and/or an abundance of eggs and early larvae were considered to represent spawning areas. While the measures used to identify spawning areas do not necessarily constitute unequivocal and absolute evidence of spawning at the time and site of a collection, they were considered precise enough to evaluate the question of whether or not white shrimp spawning activities were restricted to a few discrete, definable habitats as opposed to being a more widespread, regional phenomenon. The hypothesis that white shrimp spawning might be restricted to a few discrete sites has arisen based upon the general difficulty that mariculture personnel responsible for collecting brood stock from the wild and other researchers have historically experienced in finding fertilized white shrimp females except in a few areas--one of which is located near the proposed brine disposal site (Fig. 1).

All the known white shrimp "spawning sites" and much of the 46-47 m depth contour offshore Texas historically characterized by high numbers of spawning brown shrimp fall largely within a single bottom sediment

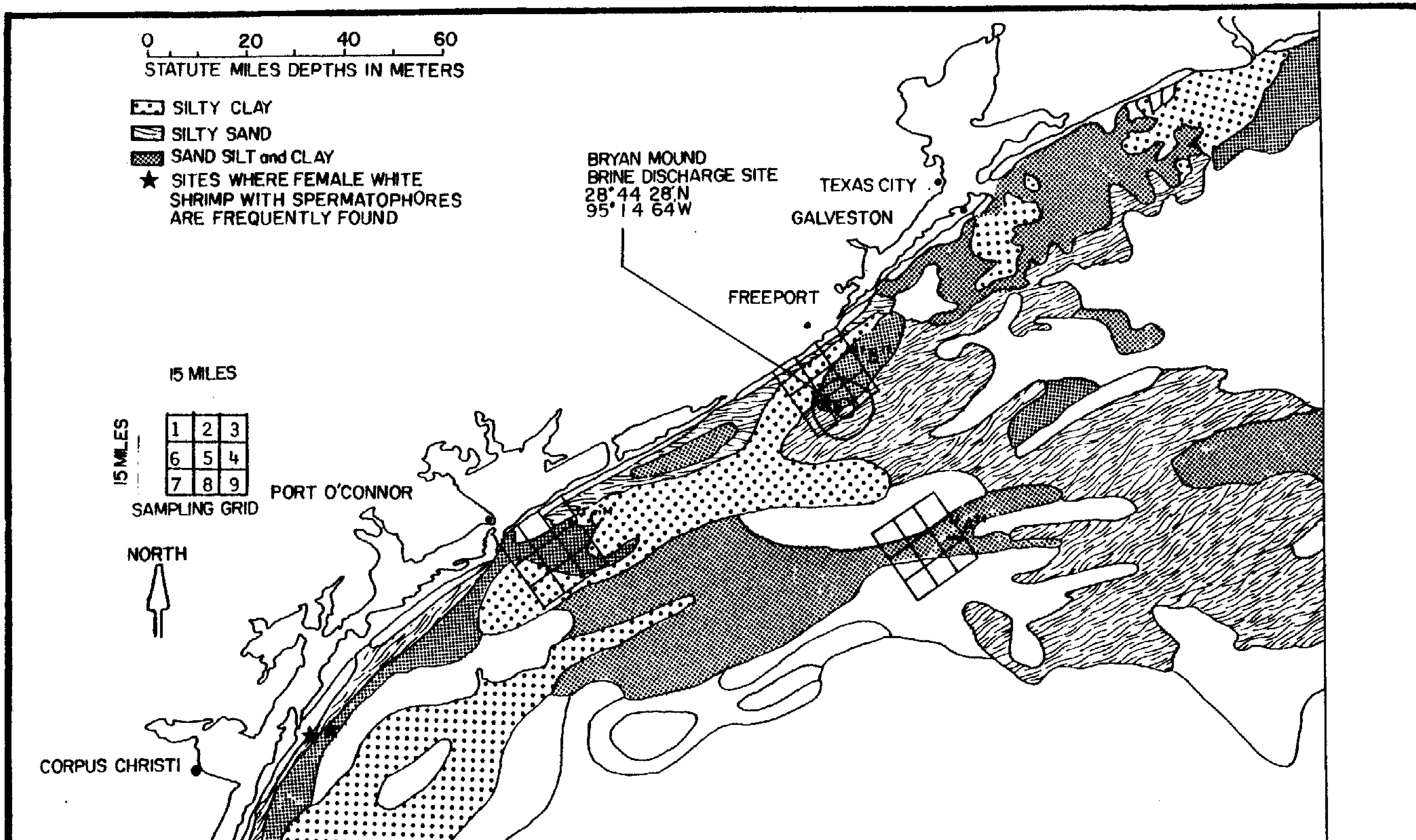

Fig. 1. Location of known or expected shrimp spawning sites offshore the Texas coast.

type, judging from historical maps of sediment distribution (Fig. 1). This fact, in conjunction with the recently discovered information that particular fatty acids, sterols and carotenoids (for which certain sediments may be a sink) are necessary to induce ovarian maturation in penaeid shrimp (Middleditch et al. 1979, Middleditch et al. 1980), lend credence to the hypothesis that localized areas or specific bottom types could be singularly important in shrimp reproductive cycles (Caillouet and Baxter 1973). Thus, it was also a goal of our program to characterize the physical and chemical nature of the areas where shrimp were believed to be maturing and spawning.

The specific objectives of the program were to:

- Describe the seasonal and spatial abundance and size distribution of sub-adult and adult brown and white shrimp in the vicinity of the brine disposal site and surrounding area;
- Determine the proportion of sexually mature brown and white female shrimp within the size range capable of attaining maturity, and describe their seasonal and spatial abundance in the vicinity of the brine disposal site and surrounding area;
- Determine the seasonal and spatial abundance of *Penaeus* sp. eggs, larvae and postlarvae in the vicinity of the brine disposal site and surrounding area;
- Describe bottom habitats (sediment and near-bottom water) represented in the study area in terms of their key physical and chemical attributes; and
- Based upon the above, define shrimp spawning areas, relating them to season, location, depth, hydrographic data and sediment properties, and to the proposed diffuser site.

The investigations were conducted during the period October 1979 to December 1980. Sub-contractors who participated in the program included Drs. A.L. Lawrence, J. Brooks, and H. Armstrong of Texas A&M University, and Dr. B. Middleditch of the University of Houston.

SECTION 2

SUMMARY AND CONCLUSIONS

Brown shrimp were abundant in shallow, nearshore ($\leq$ 20-m deep) and offshore ($\approx$ 40 to 50 m) habitats, but spawning adults were restricted to offshore areas. Subadult brown shrimp traverse the nearshore area during their summer emigration to offshore spawning grounds, and postlarvae are believed to migrate through the nearshore zone during summer through late fall. If postlarvae overwinter in the nearshore area, they probably are located in the sediments. This habitat was not sampled in this program. In the habitats which were sampled, postlarvae were found neither represented in the water column nor in the sediment samples collected during winter. As brown shrimp spawning is greatest in offshore areas during fall, and postlarval brown shrimp do not arrive to the nursery grounds until spring, it is hypothesized that they overwinter in the sediments at the point they have reached at the onset of unfavorable water temperatures. The diffuser site is sited in a location which should minimize any detrimental effects on brown shrimp spawning activities--with the possible exception of impacts on overwintering postlarvae.

White shrimp were markedly more abundant within 8 km (5 mi) of the beach than elsewhere in nearshore zones, and were more abundant in block B than in block C. Spawning of white shrimp occurred throughout summer, peaking during June and July. There was little evidence that white shrimp spawning sites were restricted to specific localities within the 8+ km band of spawning habitat along the beach. Relocation of the diffuser from 8 km (5 mi) to 19 km (12 mi) offshore has obvious mitigative benefits in terms of possible impacts to white shrimp.

Multivariate analyses of an array of environmental variables failed to delineate any unique groupings of stations which correlated with the presence of spawning white shrimp (which have been suggested as having specific spawning sites within the spawning depth range). Results of the discriminate function analyses, however, showed sites with and without spawning white shrimp during June differed significantly in terms of a suite of attributes, primarily sediment sterols, organic carbon, levels of carotenoids in prey organisms and particle size. (Good relationships were not found for brown shrimp.)

SECTION 3

STUDY AREA AND METHODS

Three areas were studied to determine the presence and magnitude of shrimp spawning within them (Fig. 2). One block was located approximately 48 km (30 mi) offshore from Freeport, Texas (block "A"), one just offshore from Freeport (block "B"), and the third block was just offshore from Port O'Connor, Texas (block "C"). The offshore block was in brown shrimp fishing grounds, while the two inshore blocks are located in the white shrimp fishing grounds. Each block measured 24 x 24 km (15 x 15 mi) and was divided into nine subblocks each being 8 km (5 mi) on a side.

Each subblock was sampled in late October or early November 1979, in late February or early March 1980, and in May, June, July, August and September 1980 (Table 1). To maximize the likelihood of locating spawning populations, a two-tiered effort was performed.

TABLE 1. DATES OF COMPLETED SPAWNING SITE CRUISES

Cruise Number	Dates
One	24-30 November, 6-7 October 1979
Two	25 February-1 March, 7-10 March 1980
Three	5-14 May 1980
Four	3-11 June 1980
Five	9-16 July 1980
Six	12-20 August 1980
Seven	3-11 September 1980

To locate concentrations of sub-adult and adult shrimp, three 12-m trawl tows were made in each subblock. The locations within the subblocks where the trawls were made were those which the vessel captain (an experienced shrimper) and the scientific party felt would be most likely to produce shrimp (judging by season, depth, weather conditions, time of day, previous catches, and experience). Each of these "search and survey" trawl tows were of 10-min duration and were made at night in brown shrimp habitat (Block A) and during the day in white shrimp habitat (Blocks B and C). Twice during the study, grab samples of sediments were taken in each subblock using an Ekman or Ponar dredge. A single grab was obtained at all but one subblock where five replicates were obtained. Sediment samples for analysis of particle size and total organic carbon levels were collected in fall 1979 (October-November) and summer 1980 (June). Sediment samples for analysis of fatty acids, sterols and carotenoids were taken during winter 1980 (February) and

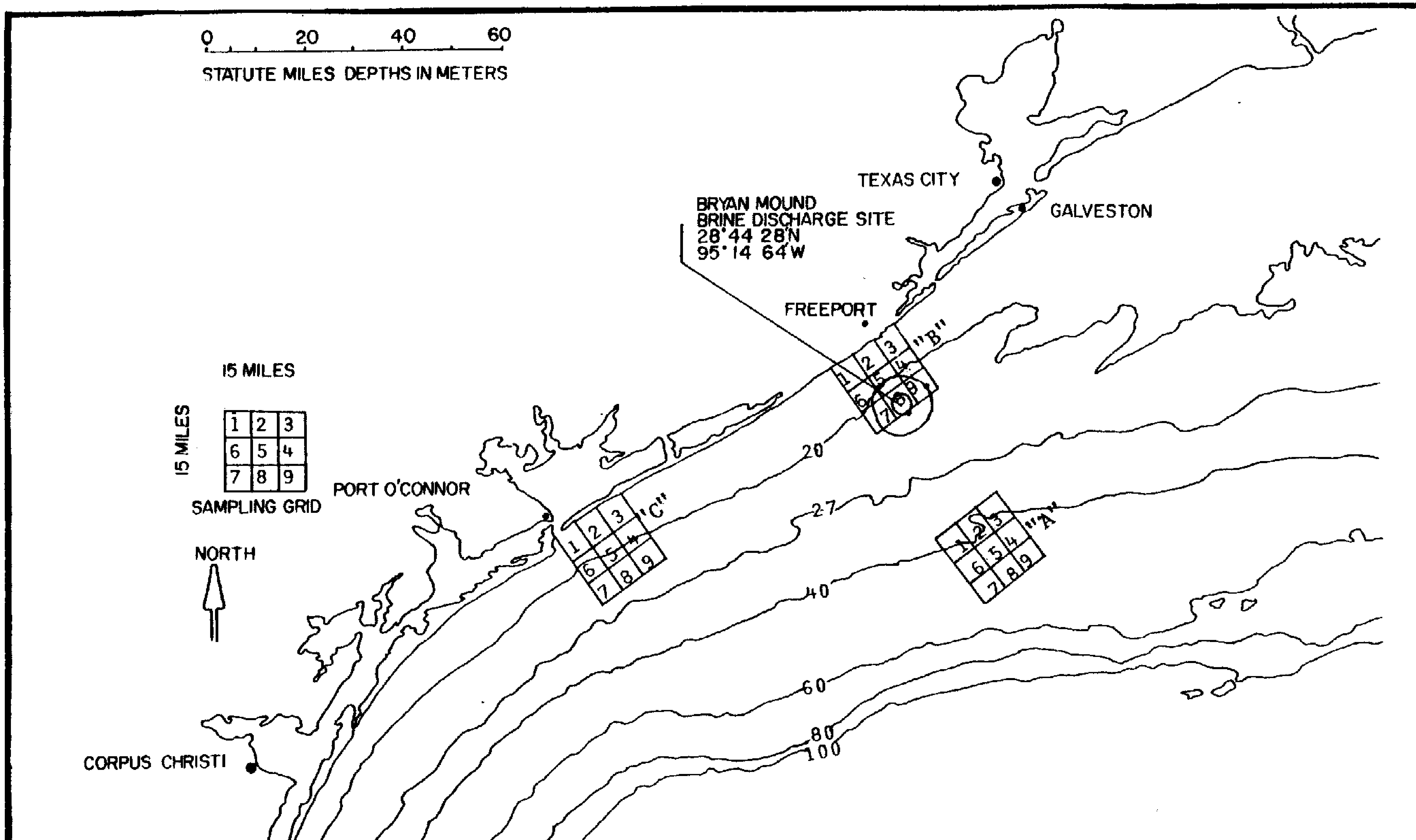

Fig. 2. Location of sampling stations. Brown shrimp habitat (Block A), white shrimp habitat (Blocks B and C).

summer 1980 (June). Benthic sleds were used to obtain epifaunal and infaunal samples from each subblock during winter and summer 1980 for analysis of sterols, fatty acids and carotenoids. The purpose of these samples was to allow a comparison of biochemical profiles of the sediments and biota in terms of their relative importance as sinks for materials required by shrimp for maturation.

Hydrographic data (water temperature, conductivity and dissolved oxygen levels) were taken using a Hydrolab (Model 4000) meter at the bottom, middle and surface of the water column in each of the 27 subblocks sampled in the search and survey effort and at each station sampled in the intensive effort. Weather conditions were also recorded.

In each row of three subblocks parallel to shore, one subblock in which the most shrimp were obtained (cruises 1-3) or in which the most mature shrimp were obtained (cruises 4-7) in the "search and survey" trawls, a second, intensive sampling effort was performed (within four hours of sunset for the inshore blocks). For this effort, three more trawls (15 min), three double oblique bongo net tows (0.333 and 0.505 mm mesh sizes, fitted with flow meter), three Ekman dredge grabs, and three benthic sled tows were taken. The benthic sled was unavailable for use on cruise one due to difficulties in its acquisition, but was deployed as planned on cruise two. Since the objective of the use of this gear was to capture shrimp which may have been overwintering in the sediments, its regular use was discontinued after cruise two.

The Ekman grab was replaced with a more efficient, similar apparatus, the Ponar grab, on the second cruise. Samples from bottom grabs in this sampling effort were planned to be utilized in an attempt to sample shrimp eggs which were expected to be very close to the sediment surface. No shrimp eggs were found in any samples from the first two cruises. Thereafter, sediment samples were not analyzed for shrimp eggs. A Gulf V plankton sampler (0.200 mm mesh) mounted on runners for bottom deployment was utilized on the remaining cruises (3-7). This equipment sampled shrimp eggs and larvae in the bottom water strata in which they are reportedly the most abundant (e.g. Heegard 1953, Temple and Fisher 1965).

Trawl catches were emptied on the deck and initially sorted for white shrimp, brown shrimp, and pink shrimp. Brown, white and pink shrimp were quickly placed in buckets of freshly obtained seawater. The remainder of the catch was sorted into "other penaeid", "other invertebrates" and "finfish" groupings. Total number and total weight of pink shrimp was obtained as well as total weight of the "finfish", "other invertebrate" and "other penaeid" groupings. Brown and white shrimp were processed individually as described below.

Brown and white shrimp were individually measured for total length (tip of telson to tip of rostrum), counted, sexed and assigned a stage of maturity based upon visual examination following Brown and Patlin (1974), Cummings (1961) and King (1948). Five maturity stages were used for females (1=no development; 2=slight development; 3=advanced development; 4=mature, fully developed; and 5=spent), and three stages of males

(0=no visible development of terminal ampule; 1=terminal ampule visible but small and; 2=terminal ampule visible and enlarged). If greater than 100 shrimp were taken in a tow, a subsample of 100 was individually processed.

As the shrimp were being individually processed, representatives of each species were divided into three size groupings for which total weight and total number in the weight were obtained. On cruises one and two, the three length groups were: <125 mm, 125-170 mm, >170 mm. The groups were defined as those with no development (<125 mm), those among which only males could be mature (125-170 mm), and those among which both males and females could be sexually mature. Starting with cruise three, the size classes were altered to <110 mm, 110-150 mm, and >150 mm. This was done since mature female shrimp were found in the medium size group as originally defined. The digestive gland and gonad from a maximum of eight males of each species from the medium size grouping were removed and immediately frozen for weight determinations and biochemical analyses. The digestive gland and gonad from a maximum of eight males and 20 females of each of the two species from the largest size group were treated in the same manner. In addition, samples of gonads were taken and preserved in modified Bouins solution for histological examination in the laboratory to determine the actual versus estimated stage of maturity.

Histological examination of the gonadal material allowed for a direct evaluation of the accuracy of the visual assessments of shrimp reproductive stage made in the field. Data from the analyses of digestive glands and gonads provided a method independent of the visual determination of stage of maturity for estimating the reproductive state of the population. The approach of sexual maturation of penaeids is signified by changes in relative weight, and lipid, carbohydrate and protein levels of storage organs (e.g. digestive gland) along with a concomitant increase of these variables in reproductive organs (e.g. gonads, see Lawrence 1976).

When mated female shrimp (white shrimp with spermatophore attached or brown shrimp in stage 4) were encountered in the samples, they were placed in 114 ℓ (20 gal) plastic garbage cans half-filled with seawater from the site of collection. This enabled us to estimate the number of eggs released and their viability, as well as to measure survival from egg to nauplii to protozoea larval stages. On a general basis, shrimp captured and spawned in the waters from areas removed from the brine diffuser site served as a control; shrimp captured and spawned in waters from the vicinity of the diffuser site served as test animals.

In addition to the field sampling program described above, an LGL biologist participated in the Texas A&M University cruises being conducted in the vicinity of the diffuser sites during periods between our cruises for monitoring purposes (see Introduction). Eight cruises each of five- to seven-day duration were made, one during each of the months from February to September 1980 (eight months). Data obtained included number, species, total length and stage of maturity for brown and white shrimp. All data were taken by LGL personnel who also assisted with other cruise activities.

Bongo net, benthic sled and Gulf V samples were preserved in 7% buffered formalin in seawater in metal capped glass jars for laboratory analyses. In the laboratory, the bongo net and benthic sled samples were placed in sub-stage illumination sorting trays and searched for shrimp larvae, which were identified to the lowest possible taxon and enumerated. Binocular microscopes were utilized for final taxonomic work, utilizing various keys (Anderson 1966, Cook 1966, Cook and Murphy 1971), and the samples were then archived. Due to budgetary and time constraints all 0.333 mm mesh bongo net samples were archived without any laboratory analyses being performed on them. Gulf V samples were washed through a 0.5 mm and a 0.2 mm mesh sieve to yield two samples, one containing organisms greater than 0.5 mm in size (penaeid mysis and postlarval stages) and one with organisms from 0.2 to 0.5 mm in size (eggs, nauplii and most protozoea). The sample retained by the larger mesh was treated as the bongo net samples. The sample retained by the smaller mesh was placed in a known volume of water and a 5% subsample obtained using a Hansen-Stempel pipet to measure precise aliquots. Eggs in these samples were compared to *Penaeus* eggs obtained from captive females and counted when they were similar in size and appearance. Nauplii could be identified only to the family level, and protozoea, mysis and postlarvae to the genus level.

A flotation method was devised for analyzing sediments for eggs. The sediments were mixed thoroughly with salt-saturated water in a 19 ℓ (5 gal) container for three minutes, allowed to settle for one minute, and the top layer of water siphoned off into glass dishes. This method caused all eggs in the sediment to float, since their specific gravity was less than that of the saturated seawater. After separation, the water containing the eggs was immediately rediluted to prevent the eggs from lysing in the saturated seawater.

Sediment samples taken for physical and biochemical analyses were frozen in glass bottles at the time of the collection, as were the epifaunal samples used for biochemical analyses. Sediments were analyzed for mean grain size, percent sand, silt, clay and levels of total organic carbon by Dr. Brooks of Texas A&M University and for levels of fatty acids, sterols and carotenoids by Dr. Middleditch of the University of Houston. Dr. Middleditch also analyzed the epifauna samples for levels of fatty acids, sterols and carotenoids. The frozen samples of eggs, digestive glands and gonads providing an alternate method for assessing stage of maturity were analyzed for dry weight, and percent carbohydrates, lipids and protein by Dr. A. Lawrence of Texas A&M University.

Samples analyzed by Dr. Brooks were divided into three subsamples, of which one was analyzed for percent organic carbon using an Oceanography International Carbon Analyzer. The second subsample was dry sieved to roughly characterize the sample's composition with respect to sand- silt- and clay-sized particles (results expressed as percent) prior to running more rigorous particle size analysis. Results of these preliminary tests provide data which can be directly compared to historical particle-size data for the region. The third subsample was also used for particle size analysis. Following determination of dry weight, the sample was soaked in Calgon solution and then wet sieved to separate the sand fraction (0-4 phi, or 1 to 0.0625 mm) from the finer silt (4 to 8 phi or 0.0625 to 0.004 mm) and clay (8-12 phi or 0.004 to 0.0002 mm) fractions. The distribution of sand-sized particles was determined by the Ro-Tap and sieve method using one-half phi increments. The distribution of silt- and clay-sized particles was determined utilizing the settling method of Folk (1974). Using these data, the size frequency distribution of the particles in the samples were characterized in terms of mean phi value, phi deviation (sorting), skewness and kurtosis. The latter measures describe the frequency distributions with respect to their symmetry and peakedness, respectively.

Sediment and biota samples analyzed for levels of fatty acids and sterols were homogenized using a Brinkmann PT 10-35 Polytron power unit and a PT 20ST generator. The homogenates were saponified by heating with sodium hydroxide solution. Sterols were extracted and, after acidification, a fatty acid extract was obtained. Each extract was dried over anhydrous sodium sulfate, reduced in volume using a Buchi/Brinkmann Rotavapor R rotary evaporator, cleaned up by a chromatography on silica gel, and examined by gas chromatography and/or combined gas chromatography-mass spectrometry. Sterols were examined as trimethylsilyl derivatives (prepared using bis [trimethylsilyl]-trifluoroacetamide) and fatty acids as methyl esters (prepared using trimethylanilinium hydroxide). Both Perkin-Elmer 3930B gas chromatographs and a Hewlett-Packard 5992A gas chromatograph-mass spectrometer were used in the analyses.

Carotenoids were released from carotenoprotein complex by the addition of acetone. Partition into cyclohexane and evaporation to dryness was followed by solution in chloroform. The sample was further cleaned up by chromatography on silica gel. Each sample was examined spectrophotometrically (absorption maxima are 420-500 mμ) to determine the total carotenoid concentration expressed in β-carotene equivalents.

The frozen samples of shrimp eggs, gonads and hepatopancreas were freeze-dried in the laboratory and their dry weights determined. The tissues were then ground and stored under vacuum until analyzed. Total lipid analysis was made by extracting the dried, ground tissue by the method of Freeman et al. (1957). The total carbohydrate in the tissue was estimated by boiling the dried tissue with five percent trichloroacetic acid, centrifuging off the precipitate, and testing the supernatant by the procedure of Dubois et al. (1956). The levels of tissue protein were determined using the colorimetric method of Lowry et al. (1951).

SECTION 4

RESULTS AND DISCUSSION

All planned samples described above were obtained (Appendix, Table 1) and have been analyzed. In addition to those shown by Table 2, additional samples (exceeding those contractually required) were obtained from a nearshore site ("D") located between blocks B and C. The purpose of these samples was to insure that if the two primary sampling blocks (B and C) had proven radically different, we would have intermediate samples to better determine the location of the transition. All data have been formatted and coded, and have been submitted to the project Data Manager.

HYDROGRAPHY

Water temperature, conductivity and dissolved oxygen levels were measured at the surface, middle and bottom of the water column at all subblocks sampled on each cruise. The bottom values of temperature, conductivity and dissolved oxygen in each subblock on each cruise are presented in Appendix Tables 2-4.

Mean bottom water temperatures ranged from about 21 to 25 C during cruise 1 (Fig. 3). During this period, block B was characterized by lower bottom water temperatures than blocks A and C which were similar in terms of bottom water temperature. The lowest bottom water temperatures observed during the study were taken on cruise 2, ranging between 13-15 C for the nearshore blocks (B and C) and between 15 and 19 C in offshore waters (block A). Bottom water temperature generally increased on each following cruise with mean temperature in block A always lower than the mean temperatures of blocks B and C. The highest bottom temperature occurred in the inner subblocks of block B during cruise 7 (30.2 C). Presumably because of its greater depth and distance from shore, block A exhibited a narrower range and less variability in bottom water temperature than did the inshore blocks over the course of this study.

Conductivity values (closely related to salinity, Appendix, Table 3b) of the bottom water were highest at block A where they were seasonally lower during cruise 1 than other months (Appendix, Table 3; Fig. 4). Blocks B and C had markedly lower conductivity values for the bottom water during cruise 4 than during the other cruises. The lowest values recorded during this study (338-413 μmhos/100 cm) were observed on cruise 4 at the inner row of subblocks in block B. The maximum conductivity value (559 μmhos/100 cm) was recorded in subblock A8 during cruise 2.

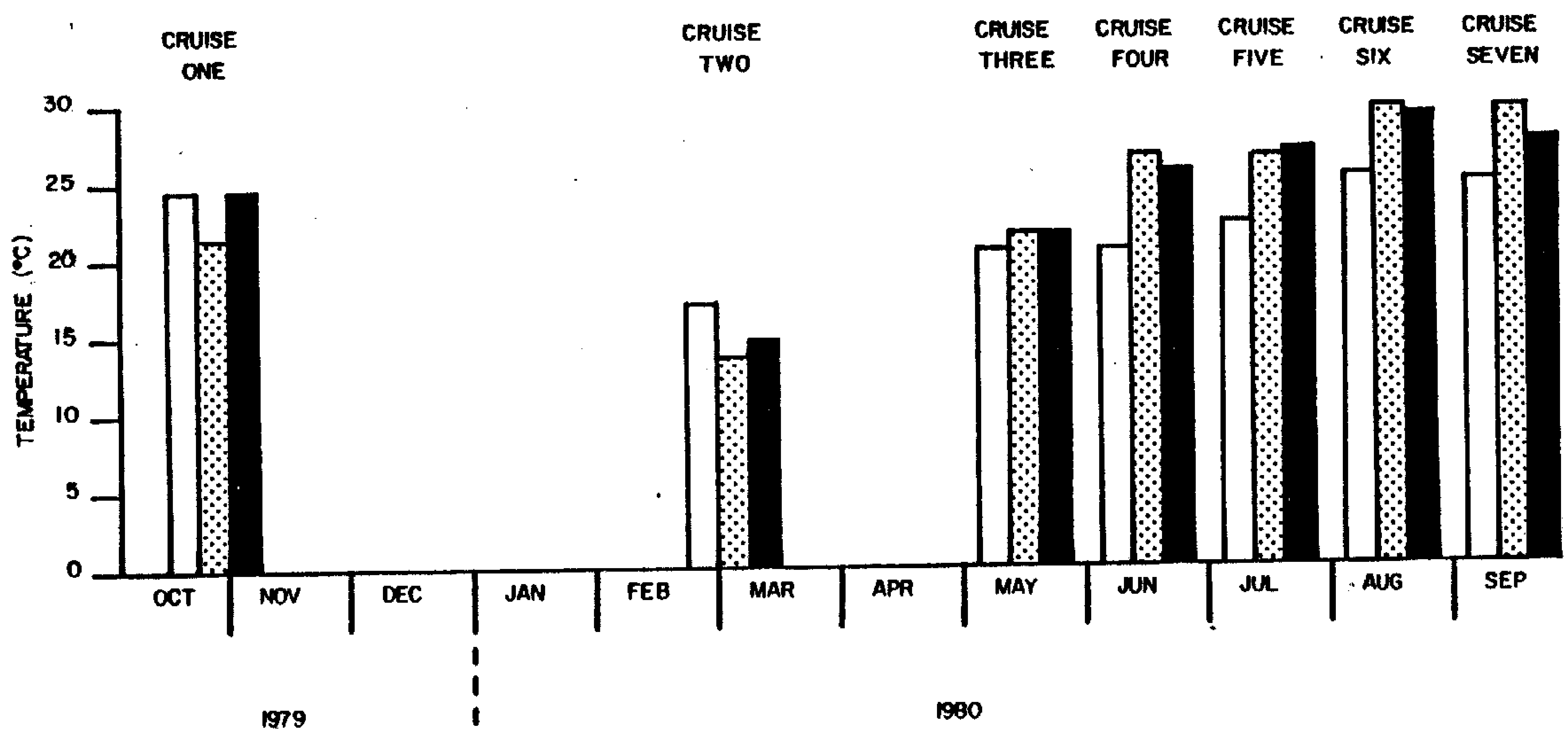

Fig. 3. Mean bottom water temperatures for blocks A (□), B (▒) and C (■) during each cruise.

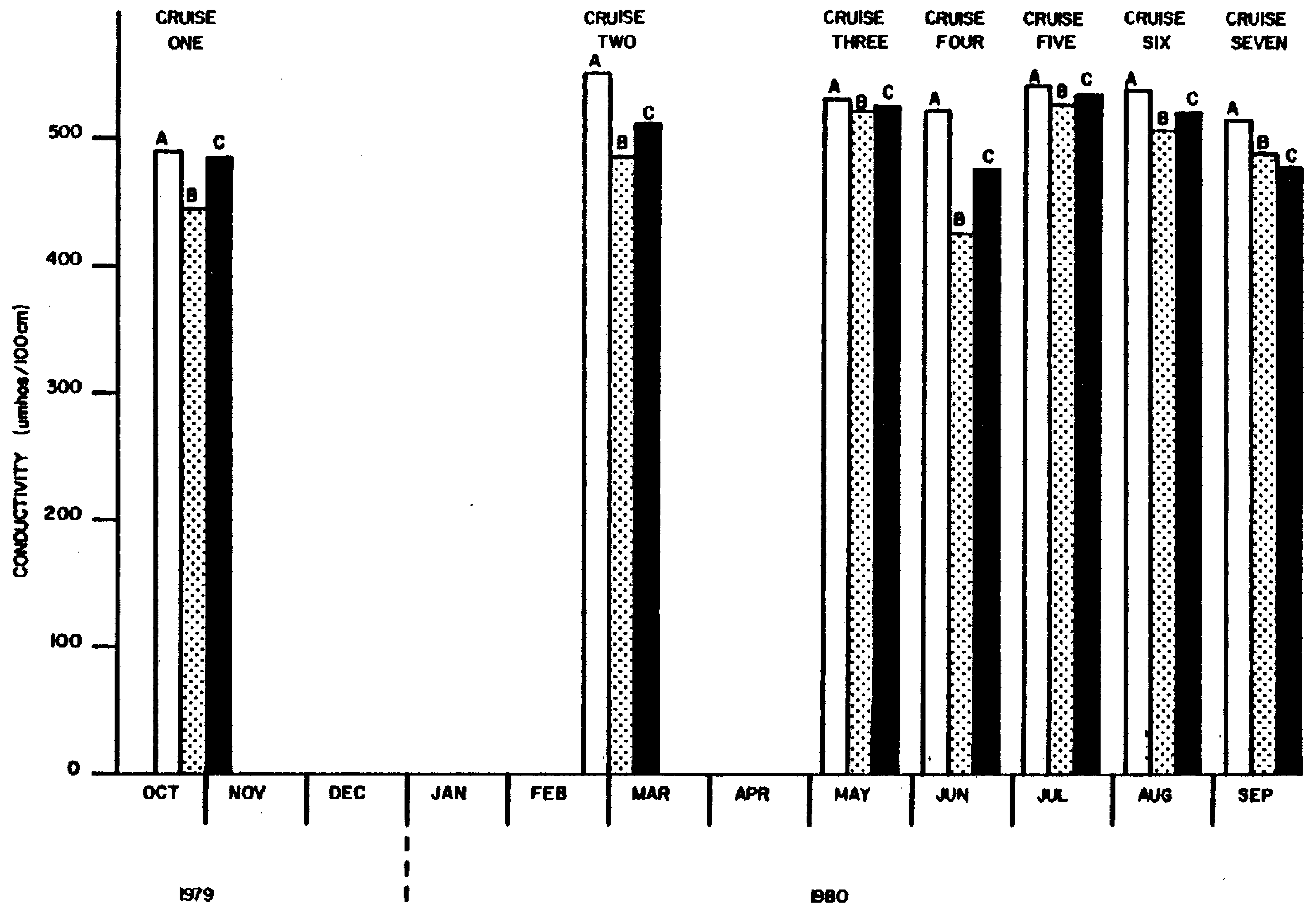

Fig. 4. Mean bottom water conductivity values for blocks A (▭), B (▒) and C (■) during each cruise.

Mean dissolved oxygen levels exceeded 4 mg/ℓ in all blocks during all cruises (Fig. 5) and were higher during cool months than during warm months. However, unusually low dissolved oxygen levels occurred in some subblocks of blocks C and A, during June and September, respectively. These low values were associated with stratified conditions. While all observed temperature and conductivity values were well within expected ranges, dissolved oxygen concentrations were observed as low as 2.4 mg/ℓ in the bottom waters of the inshore subblocks of block C during June 1980. Complete hydrological data for June are graphed in Figs. 6-8. A low salinity water mass was present on the surface in each area sampled, resulting in a stratified water column. Dissolved oxygen levels were generally lower at the bottom that at the surface in all blocks, but minimum levels in blocks A and B did not drop below about 4 mg/ℓ.

Broom (1971) and Rickards and Williams (1973) have reported that dissolved oxygen levels of 2.0 ppm (= mg/ℓ) are lethal to shrimp. It is possible that the shrimp rise in the water column to avoid bottom waters with low dissolved oxygen content (Quarberg 1974), although it is unlikely that they would continue such behavior for periods of more than a few hours. The respiratory rate of shrimp has been determined (Cox 1974, Zein-Eldin and Klima 1965, Subrahmanyam 1976) but no data were found which reported the lowest dissolved oxygen concentration from which shrimp could extract the oxygen which they require. Subrahmanyam (1976) linked increasing oxygen consumption with increasing locomotory activity in pink shrimp, *Penaeus duorarum*. Low dissolved oxygen levels may restrict shrimp activity.

SEDIMENT CHARACTERIZATIONS

Particle Size

Mean particle size of study area sediments varied among and within blocks, and between seasons (Figs. 9 and 10). Mean phi values for sediments taken from block A subblocks in October-November 1979 ranged from medium sand (1.37) to very fine silt (7.11) and the average phi value was 4.71 (coarse silt). Sediments from inshore blocks during the same periods were indicated to have been considerably smaller than those from offshore blocks (Fig. 9). Phi values for block B samples averaged 7.11 (very fine silt), ranging from 3.55 (very fine sand) to 9.52 (medium clay). In block C, the average phi value was 7.03 (very fine silt) and individual samples ranged from coarse silt to coarse clay.

In June 1980, sediments of block A samples were of similar size to those sampled from block A during fall 1979. The average phi value of the offshore samples was again coarse silt (4.58) with individual samples ranging from 2.77 (fine sand) to 6.52 (fine silt). However, in contrast to fall 1979 when inshore sediments were predominately very fine silts, the average phi values for inshore blocks B and C during June 1980 were 5.87 (medium silt) and 6.21 (fine silt), respectively. This general increase in mean particle size of inshore sediments is clearly shown by Figs. 9 and 10, and was probably related to resuspension

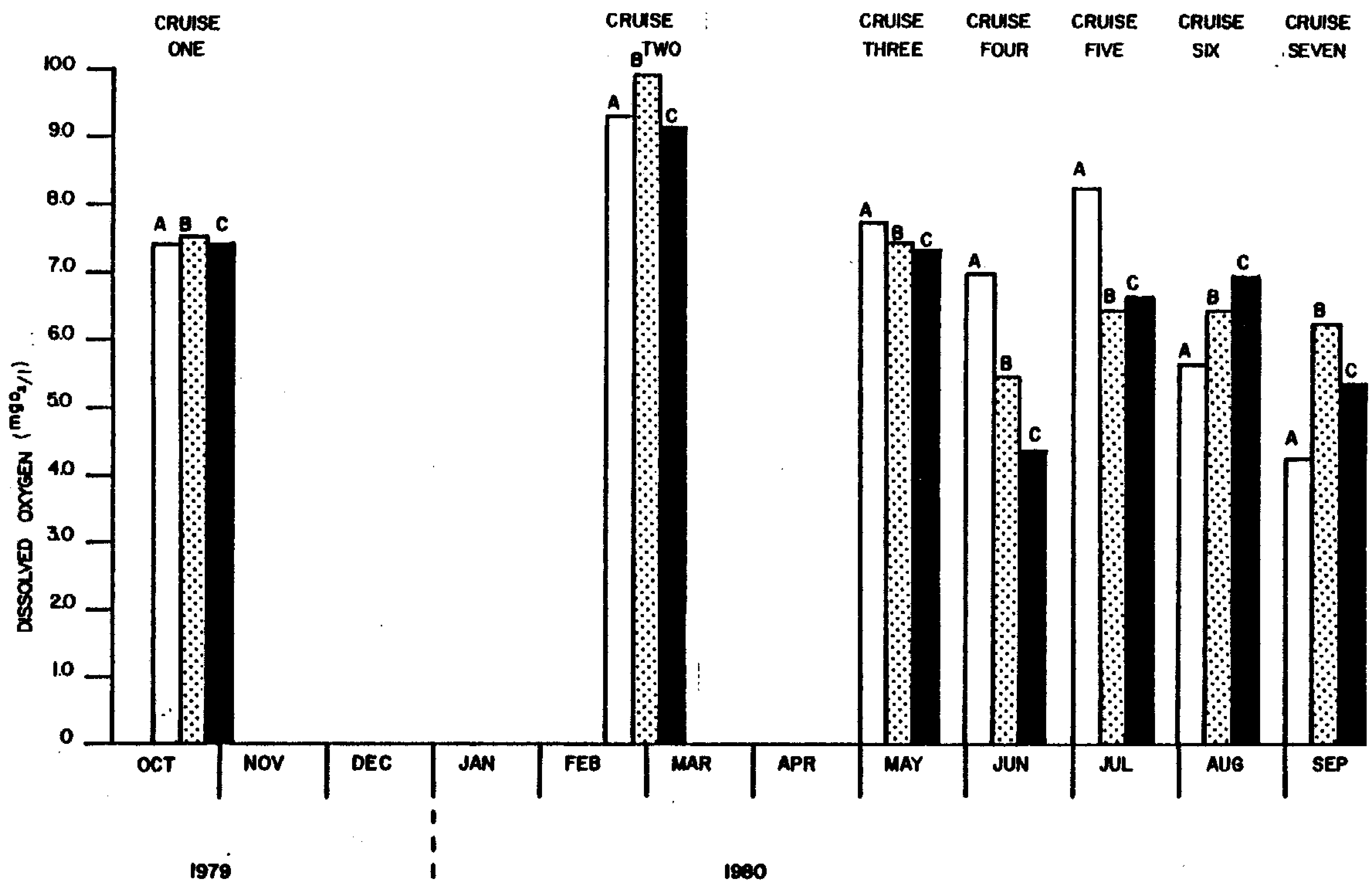

Fig. 5. Mean bottom water dissolved oxygen content for blocks A (▭), B (▒) and C (■) during each cruise.

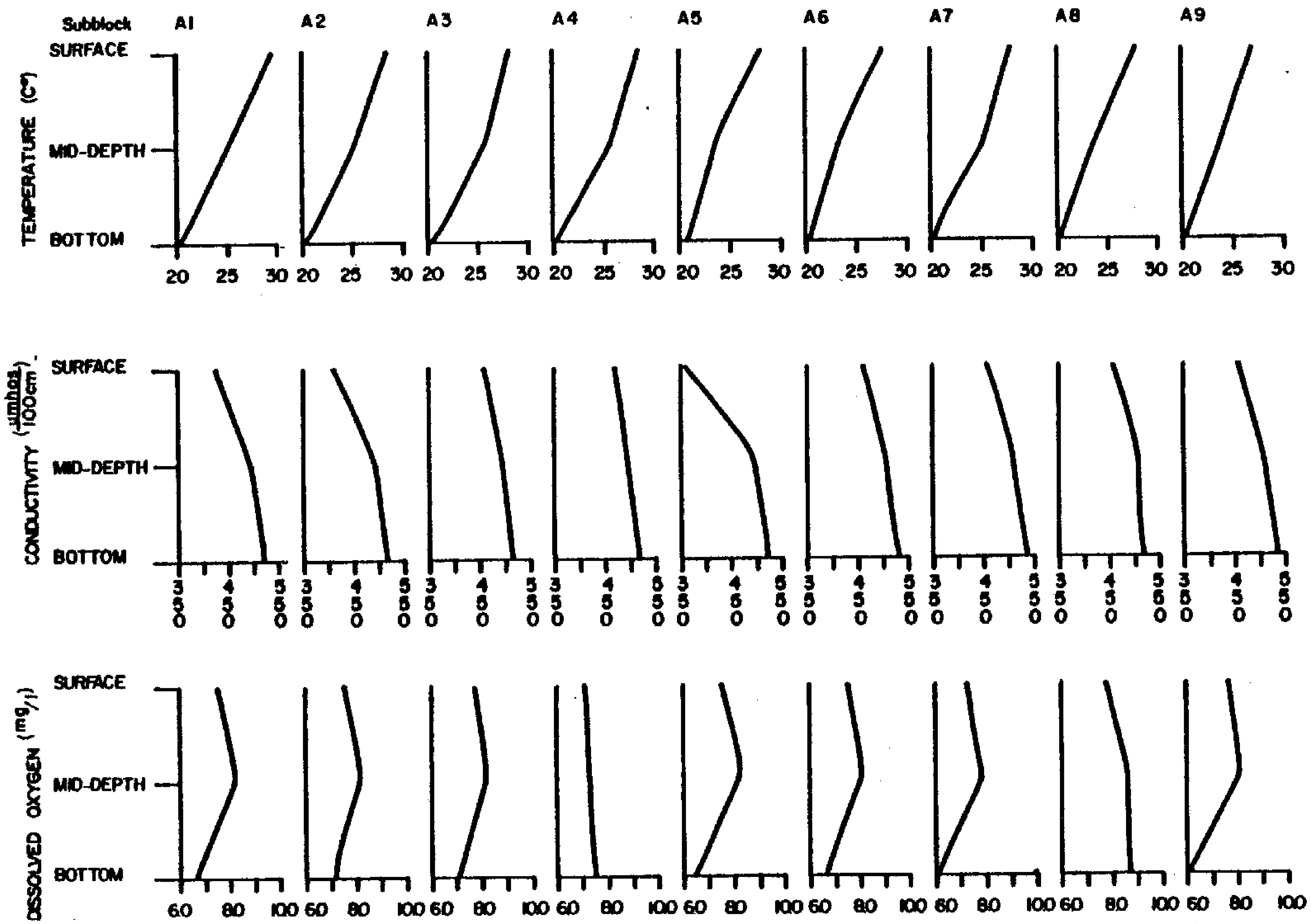

Fig. 6. Temperature, conductivity and dissolved oxygen profiles from values collected at the surface, mid-depth and bottom of each subblock in block A during cruise 4 (June 1980).

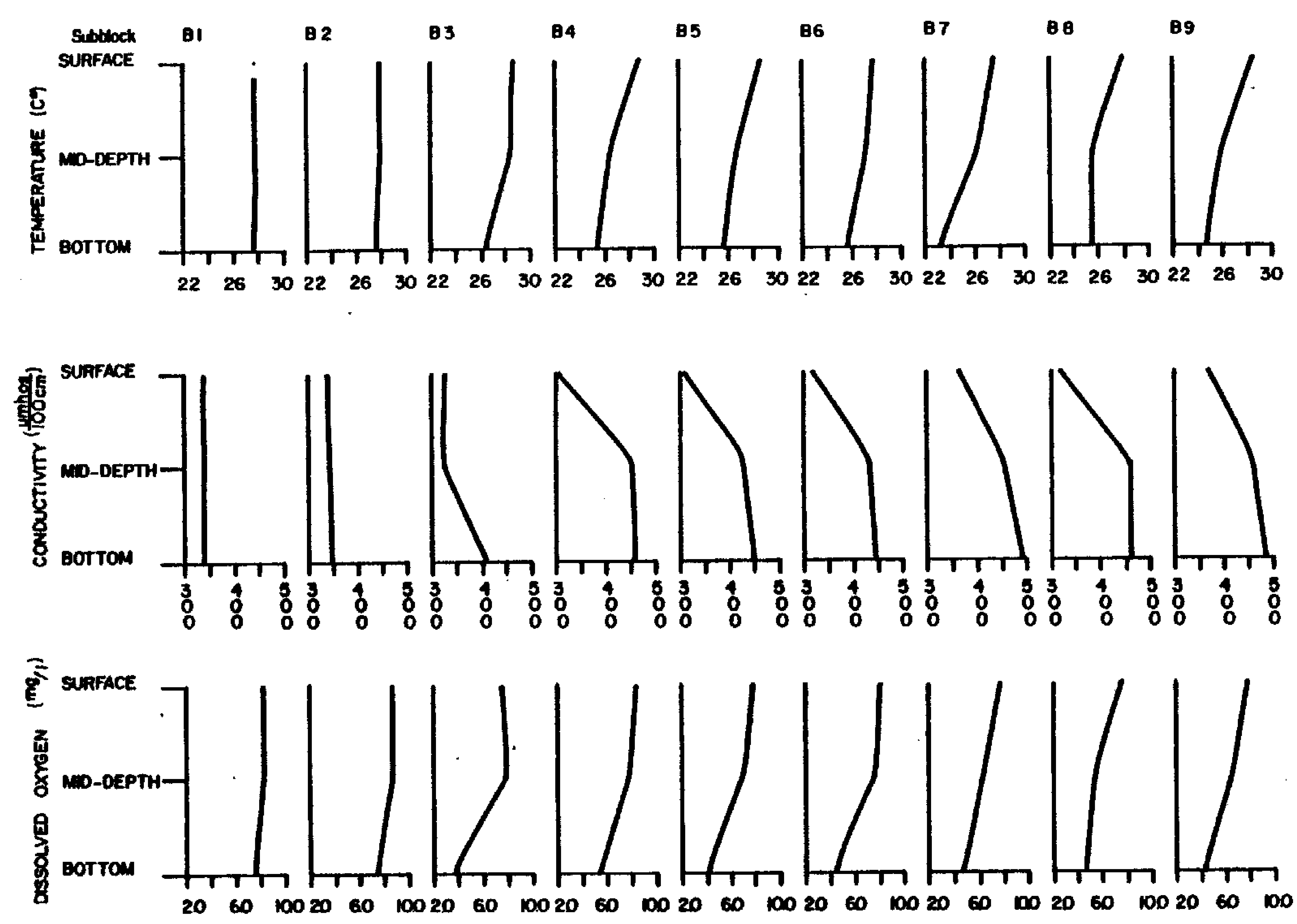

Fig. 7. Temperature, conductivity and dissolved oxygen profiles from values collected at the surface, mid-depth and bottom of each subblock in block B during cruise 4 (June 1980).

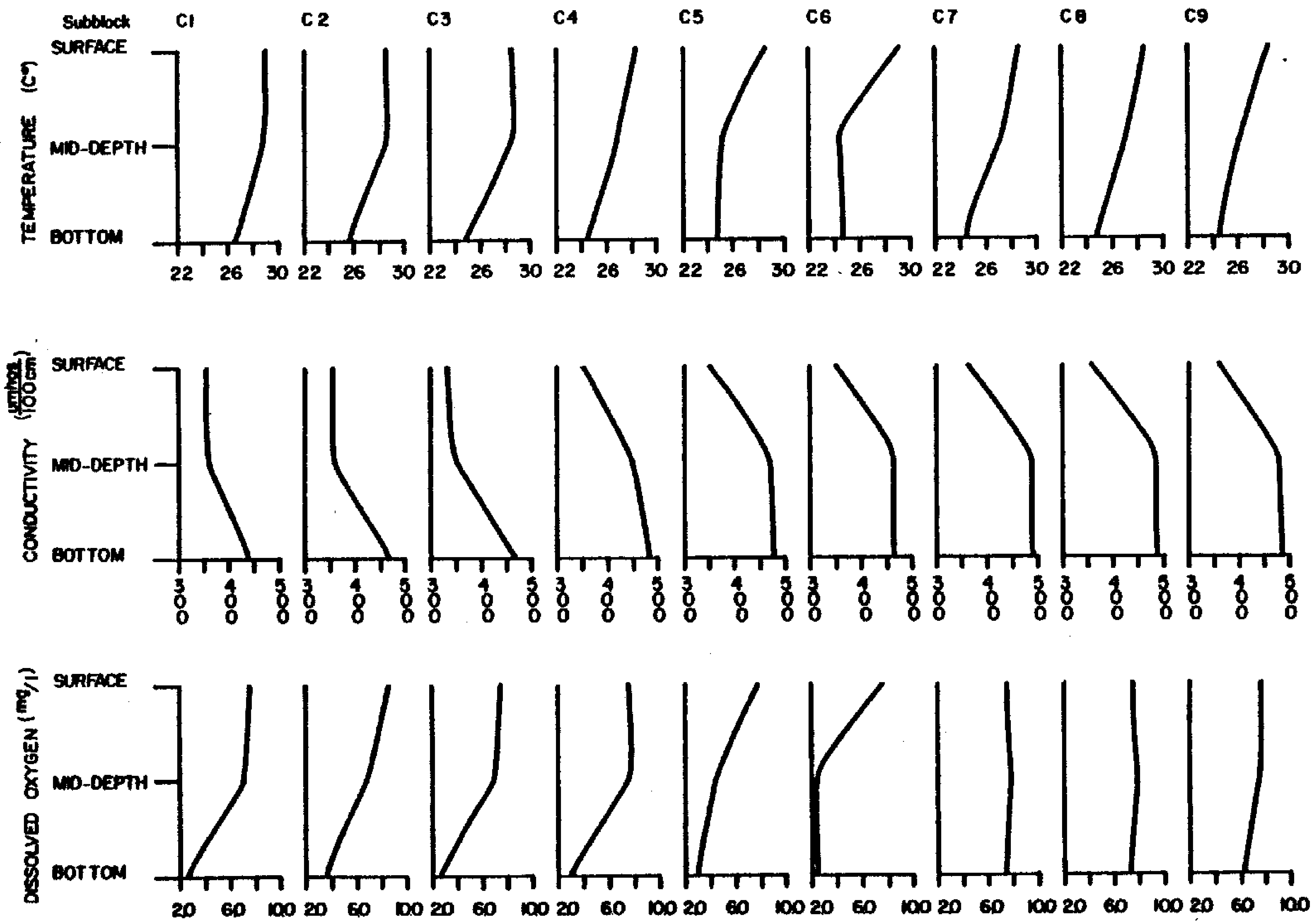

Fig. 8. Temperature, conductivity and dissolved oxygen profiles from values collected at the surface, mid-depth and bottom of each subblock in block C during cruise 4 (June 1980).

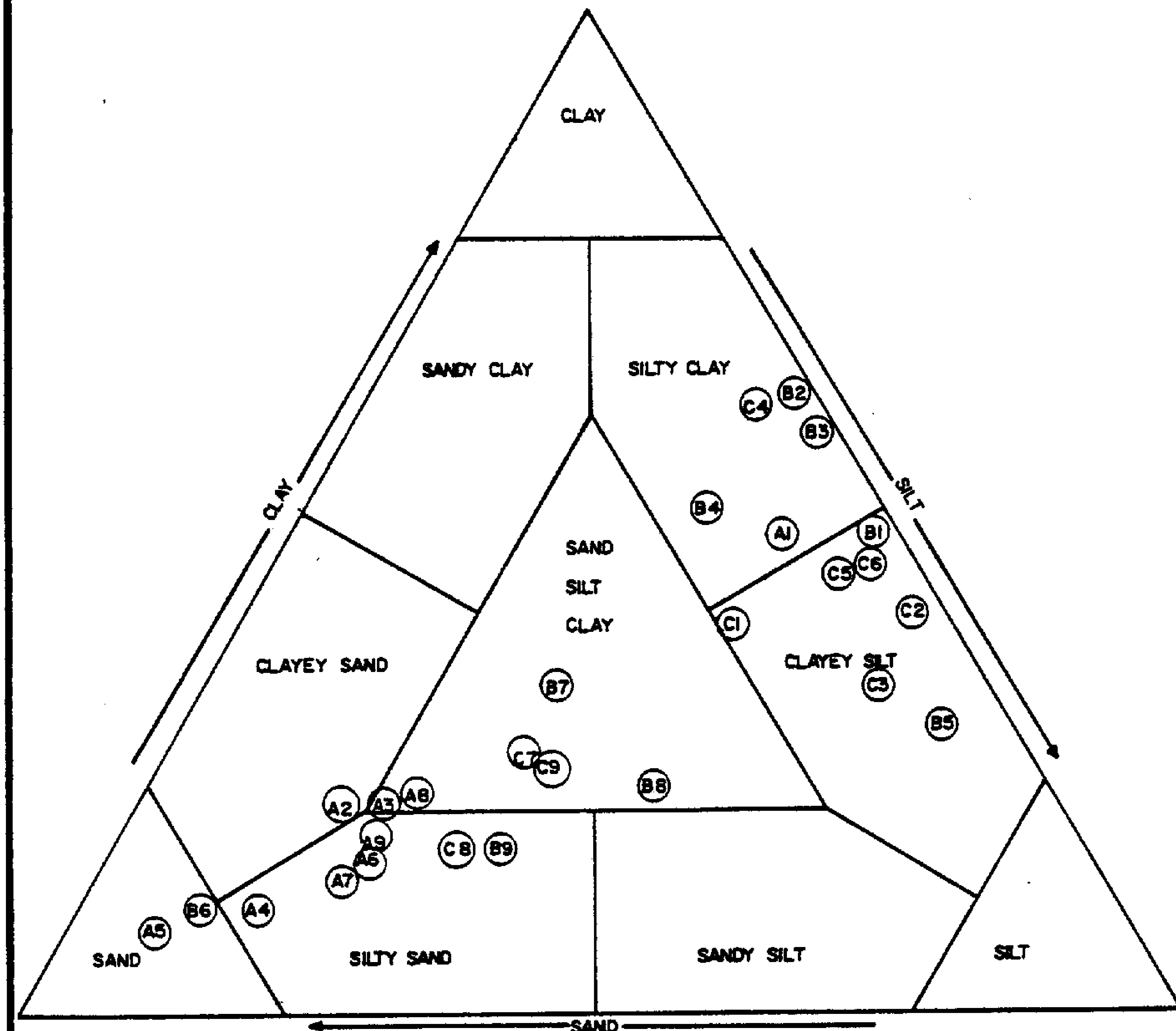

Fig. 9. Mean particle sizes in sediment samples collected in each subblock during cruise 1 (Oct-Nov. 1979) graphed by percent composition of sand, silt and clay.

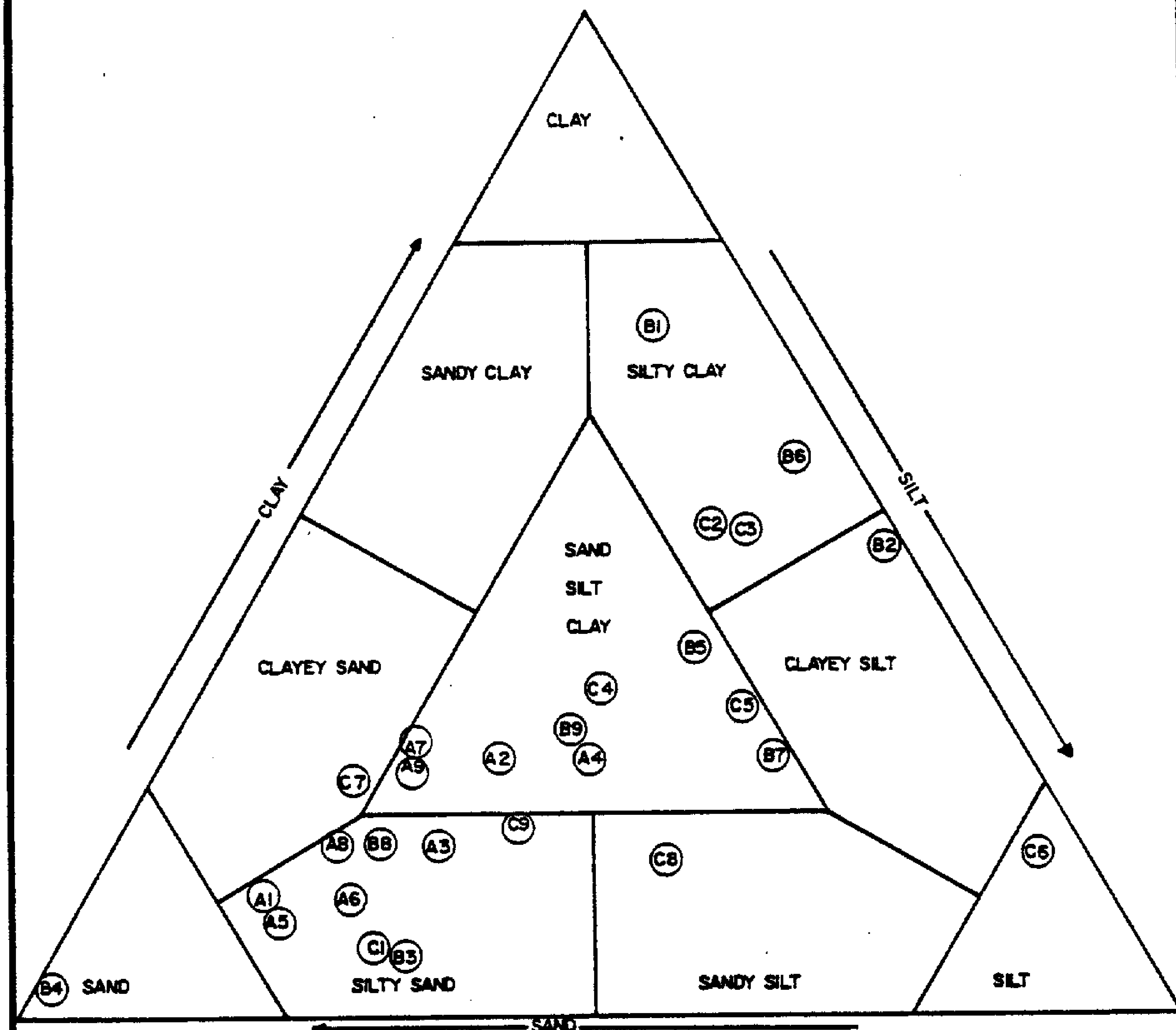

Fig. 10. Mean particle sizes in sediment samples collected in each subblock during cruise 4 (June 1980) graphed by percent composition of sand, silt and clay.

of fine materials in the nepheloid layer typical of stratified conditions. Individual samples from block B in June 1980 ranged in size from medium sand (phi = 1.00) to medium clay (phi = 9.72) and those from block C from medium sand (1.40) to coarse clay (8.13).

The phi deviation measure is a measure of sorting or spread, and approximates the standard deviation of statistics. Phi deviation values for samples taken during fall 1979 from block A ranged from 2.37 to 4.04 with the average being 2.92. Respective means of phi deviation values for blocks B and C in fall were 2.77 and 3.05; their ranges were 1.98 to 4.00 and 2.68 to 3.44, respectively. The average of phi deviation value for samples obtained during June 1980 were similar to those observed for fall samples. Respective means for blocks A, B and C were 2.75 (range 2.32-4.13), 2.52 (0.90-3.79) and 2.92 (1.83-3.75), respectively. Few samples were well sorted.

Phi skewness gives the departure of the mean from the median in terms of the phi deviation measure and is therefore a dimensionless measure of skewness, independent of the spread or deviation of the distribution. If the distribution is skewed toward smaller phi values (larger diameters), the phi mean is numerically less than the median and the skewness is negative. Conversely, skewness values are positive for a distribution skewed towards higher phi values (smaller diameters). For a symmetrical size distribution, the phi skewness measure is zero.

Skewness values for samples collected during fall 1979 and June 1980 were:

TABLE 2. PHI SKEWNESS VALUES OF SAMPLES COLLECTED DURING FALL 1979 AND JUNE 1980

	Mean		Range	
	Fall	June	Fall	June
Block A	0.52	0.54	-0.12-0.79	0.02-0.78
Block B	0.24	0.20	-0.33-0.75	-0.77-0.78
Block C	0.33	0.33	-0.31-0.64	-0.19-0.78

On an average basis, degree of skewness differed little between seasons, and distributions were skewed towards smaller particles. The highest degree of skewness was indicated for offshore stations (block A).

Kurtosis values (measure of peakedness of the distribution) are a measure of departure of the sample from a normal gaussian population curve. The kurtosis value for a normal curve is 0.65. During fall 1979 ranges of kurtosis values for samples from blocks A, B and C were 0.74 to 2.29 ($\bar{x}$ = 1.48), 0.63 to 3.90 ($\bar{x}$ = 1.12) and 0.61 to 1.82 ($\bar{x}$ = 0.86), respectively. During June 1980, the kurtosis ranges were similar to those observed in fall--samples from block A ranged from 0.71 to 3.77 ($\bar{x}$ = 1.27); those from B ranged from 0.68 to 3.43 ($\bar{x}$ = 1.20) and those from block C ranged from 0.55 to 1.58 ($\bar{x}$ = 0.84).

Organic Carbon

Levels of organic carbon (%) in bottom sediments collected during both fall 1979 and June 1980 were markedly higher in samples collected from inshore blocks B and C (sediment characterized by small particle size), than in samples collected from block A (sediments characterized by large particle size):

TABLE 3. PERCENT ORGANIC CARBON LEVELS IN SEDIMENTS

Month	Block	n	Mean	Range	Standard Deviation	Standard Error
Oct-Nov	A	9	0.36	0.16-0.79	0.17	0.06
1979	B	12	0.62	0.22-1.20	0.28	0.08
	C	14	0.64	0.26-0.93	0.22	0.06
June	A	9	0.36	0.29-0.45	0.05	0.02
1980	B	9	0.56	0.17-1.05	0.31	0.10
	C	14	0.64	0.25-0.99	0.25	0.07

Little difference was observed between seasons.

Fatty Acids

Some 21 different fatty acids were isolated from study area sediments, ranging from 14:0 to 22:6 (number of carbons:number of double bonds). The average total fatty acid concentration in sediments was considerably lower for block A (February $\bar{x}$ = 45 ppm, June $\bar{x}$ = 8 ppm) stations than average values for stations from blocks B (February $\bar{x}$ = 341 ppm, June $\bar{x}$ = 32 ppm) and C (February $\bar{x}$ = 184 ppm, June $\bar{x}$ = 36 ppm). Sediment concentrations of fatty acids observed for sediments collected in February 1980 were considerably higher than concentrations observed during June 1980 (Appendix, Tables 5 and 6). The average of the total sediment concentrations of fatty acids at block B was greater than that for block C. Three particular fatty acids (20:4, 20:5 and 22:6) have been implicated as being crucial for white shrimp maturation (Middleditch et al. 1979a, 1979b). In general, the distribution of these acids reflected a pattern somewhat similar to that shown by the total concentrations.

Concentrations of fatty acids in small, epibenthic organisms collected with the benthic sleds (Appendix, Tables 7 and 8) were much higher than concentrations in the sediments (Appendix, Tables 5 and 6). With the exception of fatty acid 18:3 which was infrequently observed at detectable levels in biota, all acids detected in the sediments were well represented in the epifauna. During February 1980, average concentration values were similar among blocks (A = 19,480 ppm; B = 15,292 ppm; C = 19,913 ppm). In June 1980, the mean concentration of fatty acids in the benthic biota (19,594 ppm) from block A was almost equal to the level observed for block A biota during February. In contrast, values for blocks B and C increased to 28,314 and 43,633 ppm, respectively. Results from benthic studies being performed by Texas A&M University at the Bryan Mound diffuser site show that benthic blooms are characteristic for April-May, and that populations are lowest in October. The decline in sediment levels of fatty acids between February and June may have been related to uptake by small benthic organisms during the seasonal bloom.

Sterols

Seven sterols were detected in benthic sediment samples, with cholesterol usually having the highest concentration (Appendix, Tables 9 and 10). The average total concentration for block A was markedly lower than the average values for blocks B and C, and the average concentrations observed during February (A = 12.0; B = 38.5; and C = 43.1 ppm) were several times higher than respective values found in sediments during June (A = 2.3; B = 4.2; and C = 4.5 ppm). Concentration levels of sterols in biota collected using the benthic sled in February 1980 averaged 4,905; 5,335; and 5,568 ppm for blocks A, B and C, respectively (Appendix, Table 11). Samples of a shrimp, *Trachypenaeus* sp., were also collected from each subblock of block A during February 1980 and analyzed. In contrast to the other and smaller epifauna in which seven sterols were usually detected, only three sterols were present at detectable limits in the shrimp (Appendix, Table 12). Nevertheless, the total concentration of sterols in the shrimp averaged 4,339 ppm--a level similar to that observed for the other biota.

Average concentrations of sterols in pooled samples of small epibenthic organisms collected by benthic sled in June 1980 (Appendix, Table 13) ranged from 25 (block A) to 38 ppm (blocks B and C). Nearly all of the total concentrations could be accounted for by cholesterol. In contrast to fatty acids, sterol concentrations in biota apparently declined during June as compared to February levels.

Carotenoids

Average levels of carotenoids in sediment samples from block A were similar during both February and June 1980 (respective values were 6.6 and 4.7 ppm), but June levels of carotenoids at the respective inshore blocks B and C (7.8 and 10.5 ppm) were lower than average levels (25.8 and 27.9 ppm), observed for these blocks in February 1980 (Appendix, Table 14). Average carotenoid levels in biota collected during February 1980 in offshore blocks A, B and C were 668, 254 and 292 ppm, respectively (Appendix, Table 15). The block A average level was over twice that for the two inshore blocks. In June, carotenoid levels averaged markedly lower in all blocks (A = 65; B = 56; and C = 70 ppm) than the levels observed for the same areas during February (Appendix, Table 15).

BROWN SHRIMP DISTRIBUTION AND SPAWNING

Brown shrimp offshore the Texas coast have been reported (e.g. Renfro and Brusher 1963, Temple and Fischer 1967) to spawn throughout the year with a major peak occurring during fall, and a lesser peak occurring during spring. Baxter and Renfro (1966) observed immigration of postlarvae into Galveston Bay virtually year-round (February-December), but with two peaks taking place one during spring and the other during late summer-fall. As will be discussed below, several researchers have suggested that the spring immigration postlarval brown shrimp may include a large component of shrimp which were spawned in fall of the preceding year, overwintered in nearshore sediments and emerged to enter the estuaries during spring. Postlarval shrimp grow and develop to juveniles or subadults in estuaries, and, based upon bait landings, are most abundant during May, June and July (Berry and Baxter 1967) as they begin seasonal movement to offshore habitats. Trent (1967) reported the total length of brown shrimp leaving Galveston Bay ranged from 60-130 mm and that size increased as the emigration season progressed.

Brown shrimp were abundantly represented in our survey catches--3,224, 2,853 and 4,234 were trawled from blocks A, B and C, respectively (Appendix, Table 16) and an additional 4,691 specimens were obtained in the intensive trawl sampling. Results of factorial analysis of variance (ANOVA) performed on the transformed abundance data ($\log_e$ [number + 1]) indicated significant differences among stations, seasons (cruises) and a significant interaction term (indicating that some cruises were "better" for collecting shrimp at some stations--a predictable result).

TABLE 4. RESULTS OF ANOVA PERFORMED ON TRANSFORMED BROWN SHRIMP ABUNDANCE DATA

Source	df	Sum of Squares	Mean Square	F Value
Total	566	257.70		
Station	26	16.15	0.621	6.43**
Cruise	6	104.60	17.433	180.43**
Station x Cruise	156	100.43	0.643	6.66**
Residual	378	36.52	0.097	

**Significant at 1% level

Brown shrimp were abundant in inshore blocks B and C only during June and August, when based upon size, they represented shrimp migrating from the estuaries to offshore habitats (Fig. 11). In contrast, abundance in offshore block A was high (520 shrimp) in October 1979, low during February-June (<100) and increased from 534 in July to over 1000 in September.

Differences in size distribution were also observed among blocks and seasons (Fig. 11). In offshore block A, adults predominated in the catches, females averaging larger than males. Female shrimp in block A averaged larger than 160 mm total length during all months sampled, and were largest during June ($\bar{x}$ = 176 mm). Mean length of females

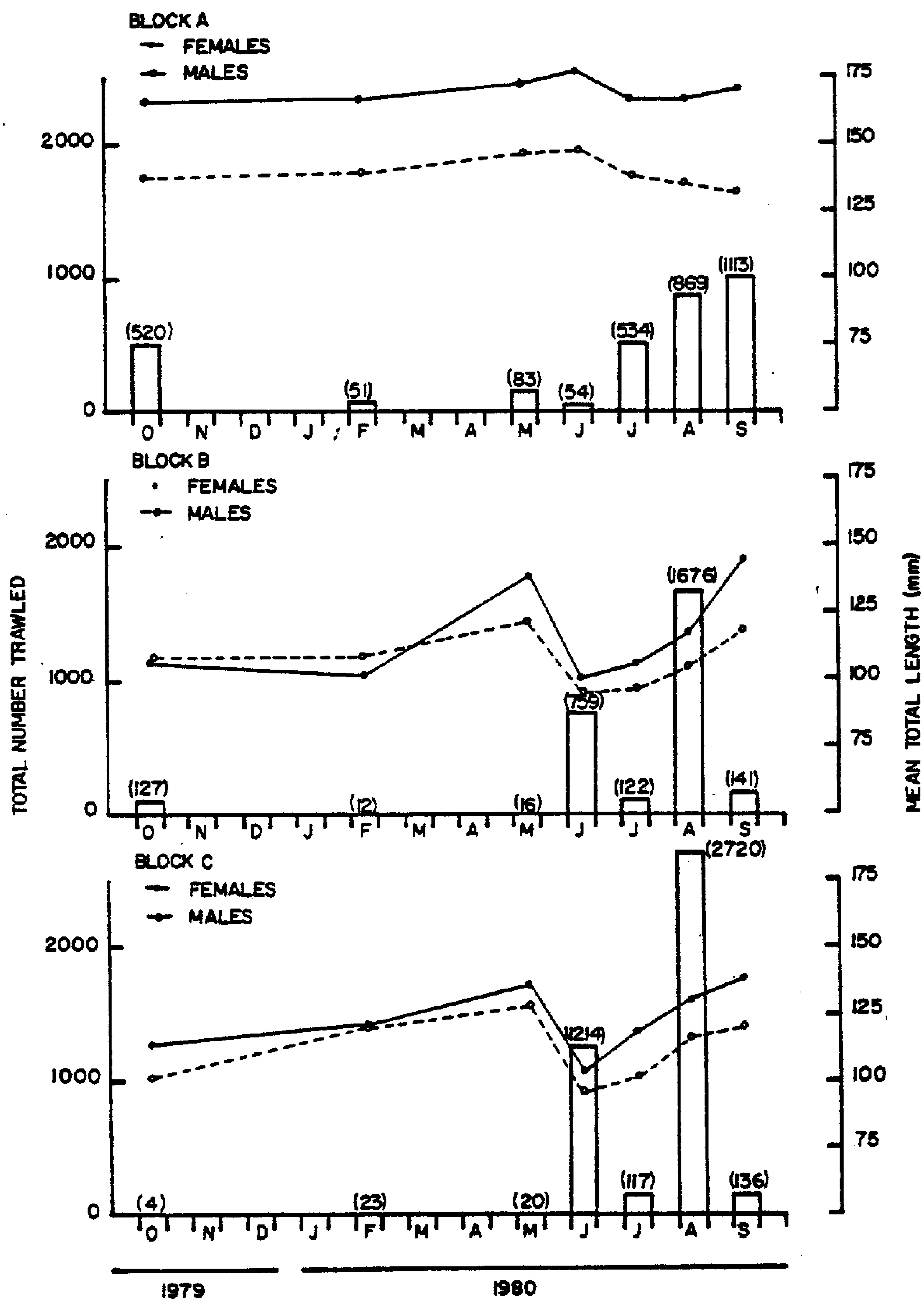

Fig. 11. Number of brown shrimp trawled in search and survey effort by block and month (vertical bars, left axis); and mean total length by sex, block and month (lines, right axis).

dropped markedly in July, presumably due to recruitment, and increased thereafter. Males were smaller than females and also averaged larger in June than during any other month. This high value was followed by a small but steady decrease in mean length during July-September.

The few brown shrimp taken in inshore blocks B and C during October, February and May averaged considerably smaller than their offshore counterparts, and the smallest brown shrimp taken inshore were trawled during June. Mean length increased after June but adult specimens of a size capable of reaching maturity were seldom encountered. The general size and abundance data suggest that blocks B (diffuser site) and C are not important brown shrimp spawning areas--an expected finding given the historical literature.

Results of independent histological analysis of gonads removed from shrimp to which we had assigned a stage of maturity based upon external examination, showed that we correctly identified 96% of the female brown shrimp that were in or near spawning condition (stages 3 and 4). Stage 1 and 2 female brown shrimp were difficult to accurately identify. For these stages, the tendency was to underestimate the actual maturity state; i.e. most we believed were stage 1 were stage 2, and many thought to have been in stage 2 were actually in stage 3. For brown shrimp males, stage 0 was easily distinguishable from stages 1 and 2, but stage 2 was difficult to distinguish from stage 1. The entire sample of stage 1 males was correctly identified, but 80% of the specimens believed to have been stage 2 were actually in stage 1.

A total of 675 female brown shrimp in spawning condition were trawled in our survey program, of which all but seven were collected from block A. A single ripe female was collected at subblock B9 in June 1980, two were collected in subblock C9 in July 1980, and three and one specimens were trawled at subblocks C5 and C8, respectively, in September 1980. The seasonal and spatial distribution of spawning females in block A is shown in the following table.

TABLE 5. NUMBERS OF SPAWNING FEMALE BROWN SHRIMP IN BLOCK A, OCTOBER 1979-SEPTEMBER 1980

ROW:	INNER				MIDDLE				OUTER				Grand
STATION:	A1	A2	A3	Total	A4	A5	A6	Total	A7	A8	A9	Total	Total
Cruise													
Oct-Nov	2	11	12	25	12	16	6	34	13	10	11	34	93
Feb	0	0	0	0	3	0	0	3	1	0	2	3	6
May	4	7	2	13	2	3	2	7	3	1	3	7	27
June	1	2	0	3	5	0	1	6	4	1	4	9	18
July	17	16	6	39	0	6	1	7	5	3	7	15	61
Aug	35	9	18	62	17	25	17	59	27	43	18	88	209
Sept	17	62	31	110	27	27	33	87	27	26	4	57	254
TOTALS	76	107	69	252	66	77	60	203	80	84	49	213	668

These data show that a spawning peak occurred during late summer and fall months, particularly during August and September 1980 (Table 5). Each row of subblocks exhibited a similar seasonal pattern, and differed little in terms of total number of mature females. The total number of brown shrimp females of a size capable of being in spawning condition is graphed along with the number and percentage of females of that population actually in spawning condition in Fig. 12. These data show a much higher percentage of females in spawning condition during May and June than during any other period, but the population size of adult females was lowest in those two months.

A total of 1,552 male brown shrimp were caught which were considered to have been mature--1,531 in block A, 6 in block B and 15 in block C. Although the trends exhibited by the data for mature male brown shrimp are considered accurate, the absolute numbers are probably in error. Although we correctly identified all immature shrimp in samples, only about 17% of the male shrimp we believed to have been mature actually proved to have been mature based upon histological confirmation. The seasonal and spatial distribution of mature male brown shrimp is shown by Table 6.:

TABLE 6. SEASONAL AND SPATIAL DISTRIBUTION OF MATURE MALE BROWN SHRIMP

ROW:	INNER				MIDDLE				OUTER				Grand
STATION:	A1	A2	A3	Total	A4	A5	A6	Total	A7	A8	A9	Total	Total
Cruise													
Oct-Nov	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	1	1	1
June	4	1	0	5	1	0	1	1	5	0	2	7	14
July	98	107	50	255	12	34	0	46	6	9	15	30	331
Aug	96	38	98	232	36	72	65	173	46	21	11	78	483
Sept	33	147	65	245	58	91	67	216	126	89	26	241	702
TOTALS	231	293	213	737	107	197	133	437	183	119	55	357	1,531

These data indicate that peak abundance of mature males occurred in July, August and September, particularly during the latter month.

Some 2,899 brown shrimp males of a size capable of being mature ($\geq$ 110 mm total length) were trawled--1,872 in block A, 314 in block B and 713 in block C. In blocks B and C, only 6 and 15 specimens were judged mature (2% for each block). Mature males were most abundant in block A and peak abundance occurred in September. Over 90% of the males trawled in block A of a size capable of being mature were deemed sexually mature during each month of July through September (Fig. 13). Considering our data for both males and females (which are in agreement), the peak spawning time for brown shrimp in the depth zones sampled was September, although limited spawning may have occurred during other months, particularly spring.

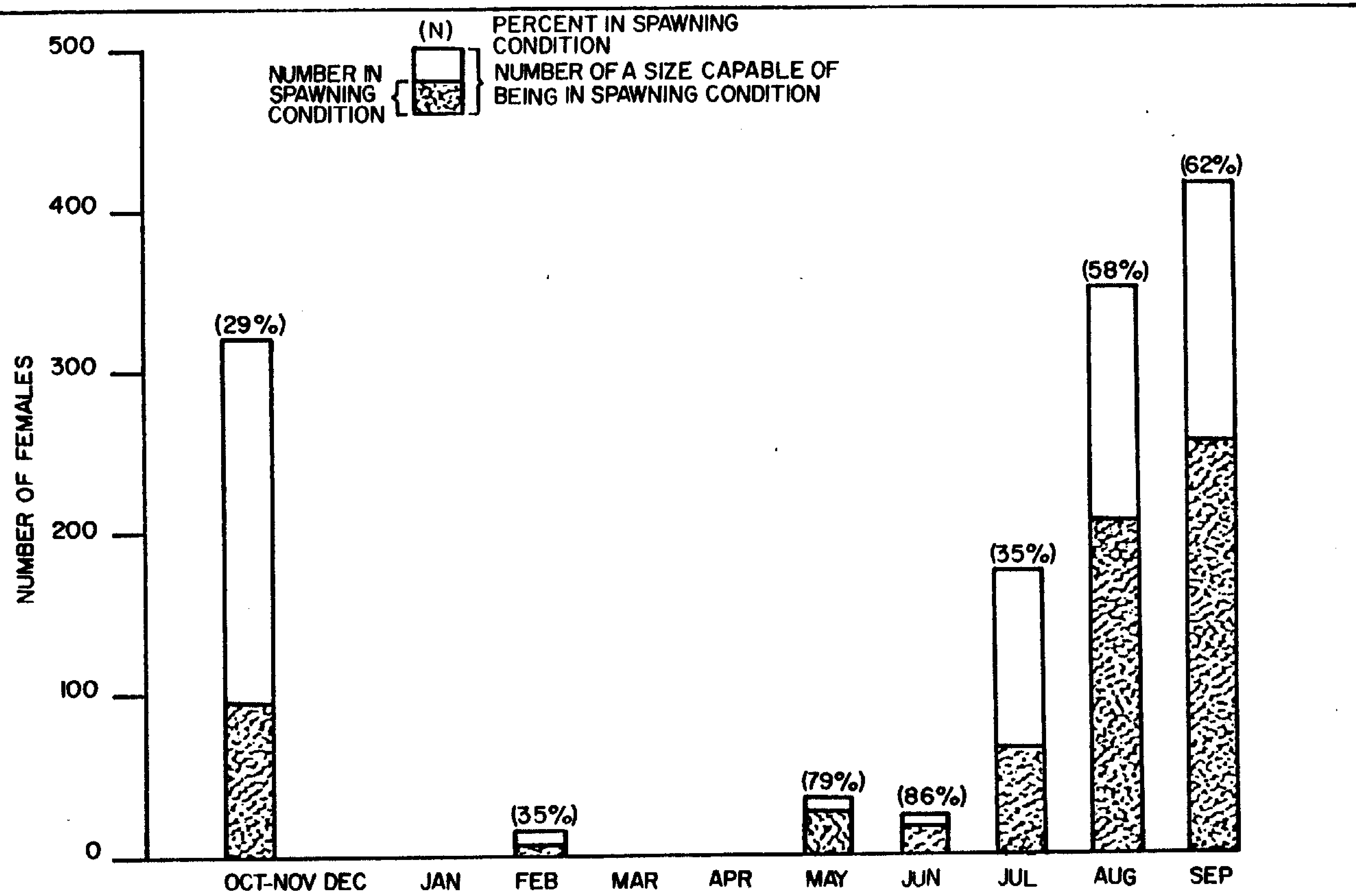

Fig. 12. Total number of brown shrimp females in spawning size classes (open bars) and proportion of those actually in spawning condition (shaded bars, % in parentheses), by month.

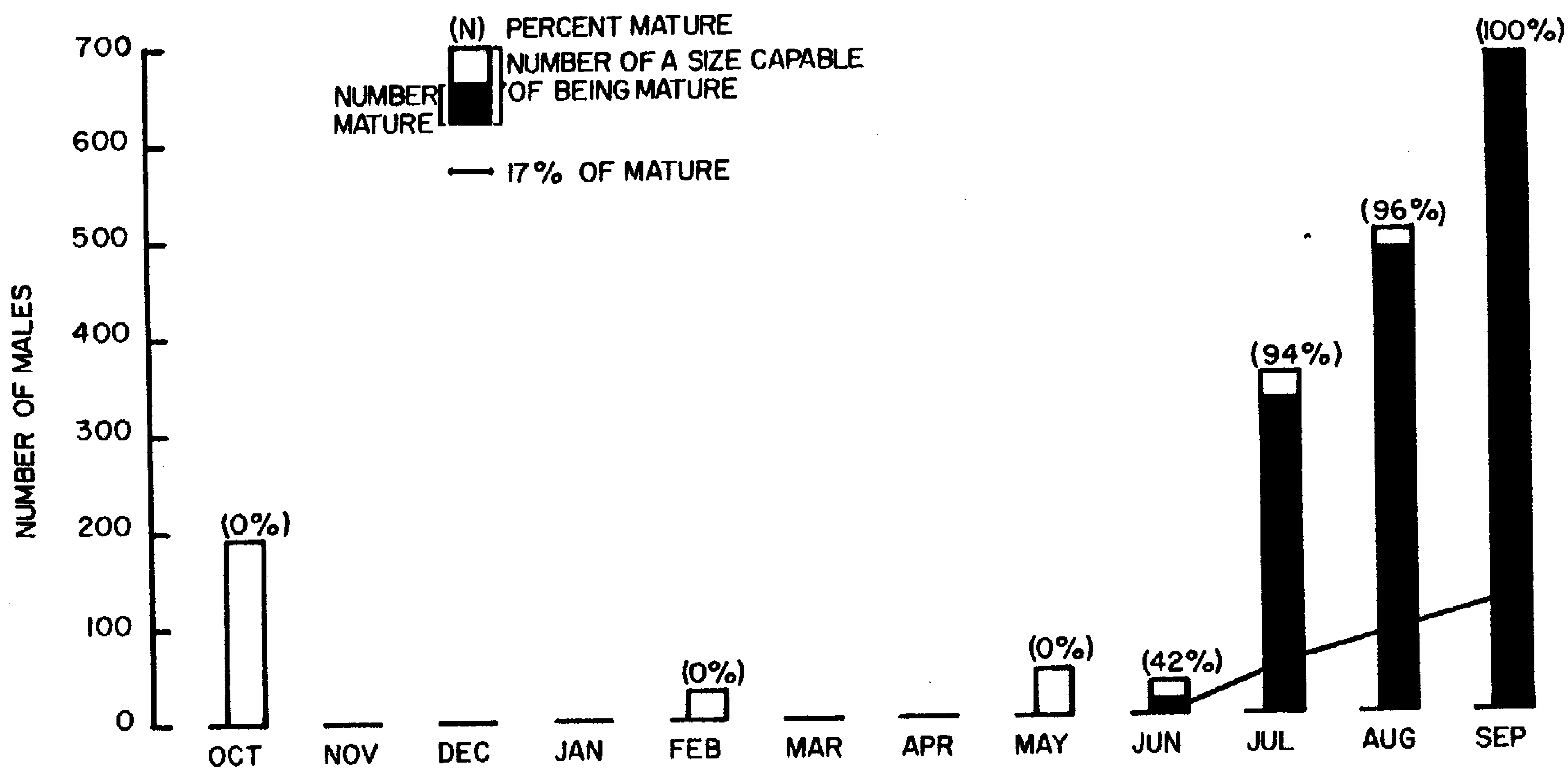

Fig. 13. Total number of brown shrimp males of a size capable of maturity (entire bar) and proportion of those actually mature (shaded part of bar, % in parenthesis) by month for block A. Line connecting dots shows 17% (number of mature males correctly identified) of total mature males.

Prior to this program, four early, major papers contributed most of what is understood about the offshore biology of brown shrimp--three dealing with postlarvae (Baxter and Renfro 1966, Temple and Fisher 1967, Aldrich et al. 1968), and one with spawning adults (Renfro and Brusher, unpublished manuscript). Renfro and Brusher (unpublished manuscript) sampled at depths of 14, 27, 46, 64, 82 and 110 m in the western Gulf in a zone extending from the Mississippi River Delta to waters offshore Mexico. Several of their findings are particularly important with respect to the findings of our program. First, results of their sampling showed spawning of brown shrimp based upon the frequency of ripe females was greater at the 46-m depth zone than at the other depths sampled. Our group of sampling stations comprising block A were thus optimally located for determination of spawning characteristics of brown shrimp. Again, based only upon the frequency of ripe females, Renfro and Brusher (unpublished manuscript) determined that there were two periods of heightened spawning activity by brown shrimp at the primary spawning depth--one in late spring and the other in fall. At deeper depths ($\geq$ 64 m), they found large females, although not abundant, to have been present year-round, with most being in spawning condition.

Our data confirm Renfro and Brusher's (unpublished manuscript) determinations that spring and fall are the periods of heightened spawning for brown shrimp in the western Gulf, but strongly suggest that the fall season is, by far, the most important. This evaluation (as well as that made for spawning depth) is supported by the *Penaeus* spp. larvae and postlarvae data reported by Temple and Fischer (1967) based upon samples taken at 14-, 27-, 46- and 82-m depth zones offshore Texas and Louisiana (see Fig. 4, Temple and Fischer 1967). Considering all plantonic stages, *Penaeus* spp. larvae and postlarvae were most abundant at the 46-m sampling depth (72% of the total catch for depths $\geq$ 27 m) where they were well represented only during September through December periods. Larval stages were most abundant in September, postlarvae were most abundant one month later in October. Our plankton data also show larvae and postlarvae in block A to have been abundant in late summer and fall. Of importance, Temple and Fischer (1967) reported postlarvae collected during August through December averaged 6 to 7 mm long, whereas those collected during January through April averaged 11 to 12 mm long.

Baxter and Renfro (1966) found at least a few postlarval brown shrimp along the beach of Galveston Island and in the Galveston entrance throughout the year, but that peak abundance (markedly pronounced, see Fig. 2 of Baxter and Renfro 1966) occurred during mid-March to mid-April. In addition, there often appear to be minor abundance peaks of brown shrimp postlarvae occurring at the passes in late summer. These findings have been verified by other studies (e.g. St. Amant et al. 1966). Baxter and Renfro (1966) found size of brown shrimp postlarvae along the beach and in Galveston entrance during January-April periods averaged 11 to 12 mm; during the remainder of the year, the postlarvae averaged noticeably smaller. Temple and Fischer (1967) pointed out this anomaly (peak of abundance of postlarvae entering the estuary occurring some six months after peak spawning offshore), and hypothesized that postlarvae from the primary fall spawning overwintered offshore, perhaps hibernating in the sediments. The latter idea was supported by the resulting work of Aldrich et al. (1968). These researchers experimentally determined that, in contrast to white shrimp, brown shrimp postlarvae burrowed into a silty-clay substrate in response to dropping temperatures (between 12-17 C) and emerged as temperatures exceeded 18 to 21.5 C. These temperature ranges approximate natural water temperature regimes and ranges off the Texas and Louisiana coasts during winter and early spring, respectively. Further support that brown shrimp postlarvae could hibernate was provided by the findings of Zein-Eldin and Aldrich (1965) and Zein-Eldin and Griffith (1966) who found that temperatures of 11 to 15 C greatly reduced or stopped postlarval growth, but permitted survival. Growth was only 0.0 to 0.6 mm per month at 11 to 15 C, as compared to 9 to 23 mm per month at 20 to 30 C.

Based upon review of all the major findings, we believe the data are consistent and support fall as the major spawning period for brown shrimp but with a minor spawn of unknown importance occurring during spring. For the minor period of brown shrimp spawning activity occurring during May and June, eggs and larvae should experience temperatures favorable for development to postlarvae ($\geq$ 24 C, Cook and Murphy 1969) and each of the stages would be aided in their movements towards the estuaries by Ekman transport which, during this season, is generally to the north (Sweet 1974). These postlarvae should arrive at the estuaries much quicker (and be of smaller size) than those spawned during fall, as explained below.

Eggs and larvae spawned during fall would not be favored by Ekman transport which, during this season, is generally to the west and southwest (parallel to the coast). Given the characteristic time-depth-temperature regime for offshore waters (Pequegnat et al. 1976) and the developmental work by Cook and Murphy (1968), the eggs spawned during fall would hatch and the larvae would attain postlarval stage by late October-early November (consistent with Temple and Fischer 1967). These postlarvae, however, would not be aided by Ekman transport in their movement to coastal estuaries as this current remains to the west and southwest until spring. Further, they would encounter a declining temperature regime, slowing growth markedly. Finally, by mid-December or early January, the postlarvae would experience water temperatures ($\leq$ 17 C) which have been shown by Aldrich et al. (1968) to induce a burrowing response in postlarval brown shrimp,and to allow for little or no growth (Zein-Eldin and Aldrich 1965). The nearshore temperature regime would not be favorable for emergence until early spring.

The hypothesis of brown shrimp overwintering is strongly supported by all the information, but has yet to be conclusively documented. However, Baxter (1969) sampled for postlarvae offshore Galveston in depths of 4-15 m during winter of 1968-1969 using a uniquely-designed benthic sled. Catch per tow values for each month of November,1968-February 1969 were 0.1, 1.2, 11.2 and 10.6, respectively. While these data were not considered adequate for predicting resulting year class strength, they do provide strong evidence that brown shrimp postlarvae were present in the sediments during winter. In our sampling program, no postlarvae were found offshore in any of 27 benthic grab and 27 benthic sled samples taken from the study area in February 1980. Either (1) our sampling effort was inadequate to collect postlarvae, (2) they were not overwintered in the areas we sampled, (3) they may have already left the sediments or (4) they do not overwinter in sediments. Of these, we believe the second possibility is the most likely, although the first is not easily dismissed. It should also be noted that postlarvae were not taken in our plankton samples during late fall or early winter.

Results of our investigations showed two well-defined cohorts of brown shrimp juveniles traversing the inshore white shrimp grounds--one in June and the other about two months later in August. The second group appeared larger than the first, both in numbers and in size. We suggest that the first group represents shrimp spawned the previous spring which arrived at, and entered, the estuaries as postlarvae in late summer and early fall. There, they probably grew until the onset of cold weather at which time they either perished or found refuge in deep water or in the sediments. Juvenile brown shrimp are typically represented in the estuaries during winter, although they are seldom as abundant then as during spring and summer months. In early spring, these shrimp resume rapid growth, approach maturation, and move offshore earlier than the brown shrimp spawned during late fall but which did not arrive at the estuary until the following spring.

The majority of the brown shrimp postlarvae from the primary fall spawn probably do not reach the estuaries prior to going into an overwintering state as postlarvae. However, since postlarval brown shrimp have been observed to be most abundant entering the bays through the passes during March and early April (Baxter and Renfro 1966), they must get very close to the shore prior to overwintering. They use the inshore nursery grounds from spring to summer and are the last cohort to emigrate. The primary cohort as hypothesized (fall spawn), would be favored over the minor one (spring spawn) in that development and growth are interrupted by cold temperature at a younger and more tolerant stage. Further, the estuarine temperature regime experienced during the period of residence is favorable for rapid growth and development.

As penaeids mature, the relative size of the gonads increases while that of storage organs such as the hepatopancreas decreases. In addition, relative percentages of carbohydrates, proteins and lipids in the gonads also change as relative levels in storage organs change. One index to the maturation stage of penaeids is the ratio of gonad to digestive glands in terms of the above response variables. For adult female brown shrimp in block A, the mean of the ratios of gonad dry weight to hepatopancreas dry weight was always markedly higher than the ratios observed for blocks B and C (Fig. 14). The organ weight ratios for block A exceeded 1.0 during October-November 1979, and during May and June 1980. These data agree well with the determinations based upon external examination of stage of maturity in that they suggest spawning activity was mainly restricted to block A with peaks in fall and spring. The ratios based upon percent lipid composition of the organs show a pattern similar to that exhibited by the weight data, with the ratio values about one-half those based upon weight (Fig. 14). The other ratios (percent

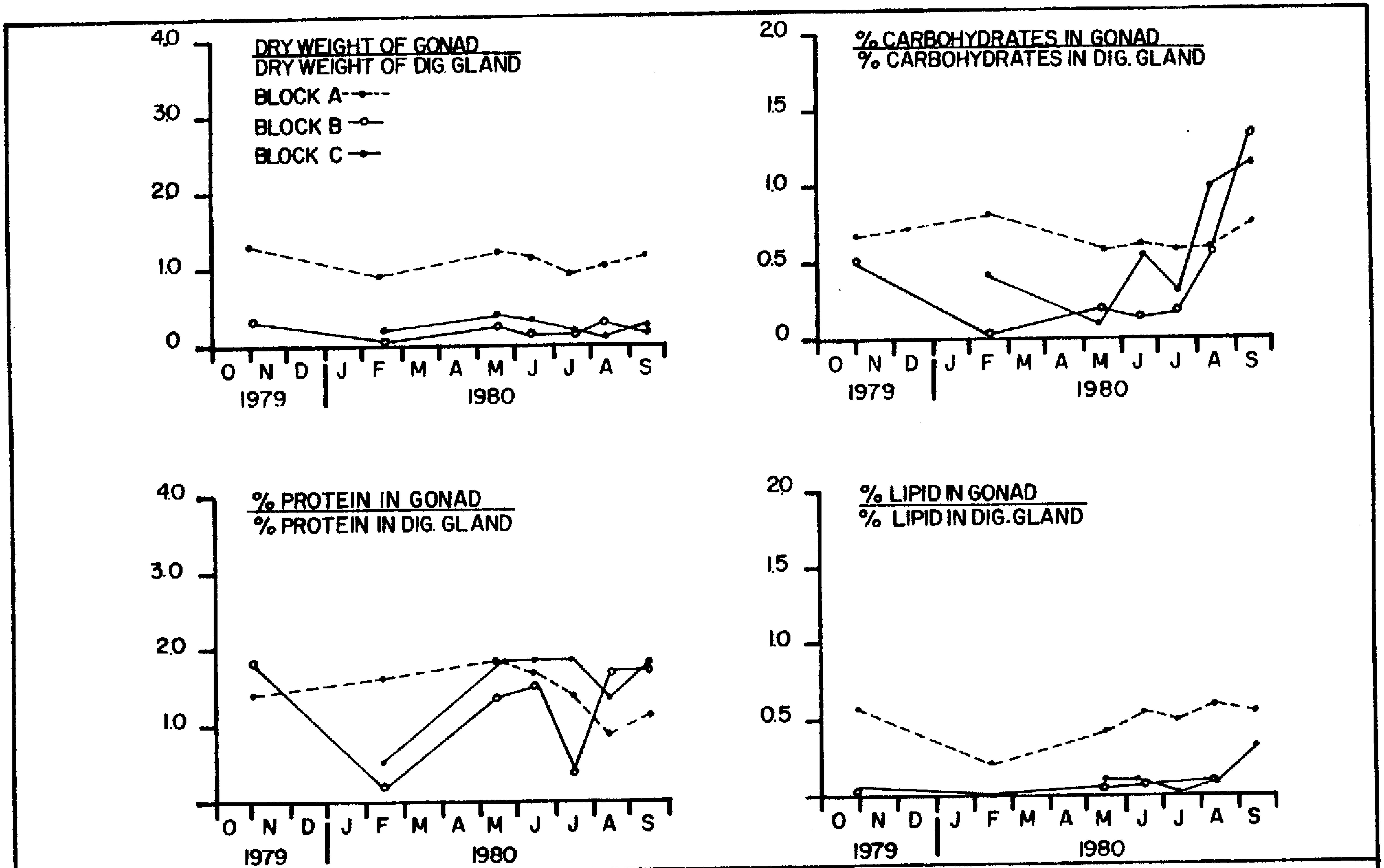

Fig. 14. Ratios of variance measures of female brown shrimp maturation indicators in gonads versus digestive glands, by month and block.

carbohydrates and percent protein) would be difficult to interpret in the absence of other information, although that based upon percent carbohydrates suggests a distribution inversely related to organ weight and percent lipid ratios.

A total of 16 stage 4 brown shrimp females were spawned on the vessel, nine during August 1980 and seven during September 1980. In August, all were taken from block A and ranged in total length from 153 to 179 mm. Estimated number of eggs (based upon extrapolation of counts of sample aliquots) released per female collected in August ranged from 22,000 to 220,000 averaging 78,000. During September, one 148 mm female was collected at C8 and produced 53,000 viable eggs. The six specimens taken from block A during September ranged from 151 to 195 mm total length, and produced an average of 116,500 eggs per female. The range of eggs produced per female in September was 26,000 to 238,000. All but one of the females collected in September from block A produced viable eggs. Not including the unsuccessful batch, the percentage of eggs that hatched to nauplii was similar between months, averaging 69% in August (range was from 53 to 97%) and 70% in September (range was 21 to 90%). During both months, 44% of the total number of eggs hatched to nauplii.

The discharge of brine at the proposed location does not appear to be a concern with respect to impacts on brown shrimp spawning activities. Brown shrimp utilizing the area are primarily either subadults in route to offshore spawning grounds, or larvae or postlarvae being transported or moving towards inshore nursery grounds. Although postlarvae are strongly suspected to overwinter outside the estuary, none were collected from the study area sediments during February. The distribution of larvae and postlarvae, their dispersal patterns and rates, and nature of transport and/or migration between the time they are abundant on the spawning grounds (fall) and the time they suddenly appear in abundance at estuarine passes (spring) remains as a major, unanswered question. The effects of brine disposal on this life history stage cannot be estimated without this information. In future and ongoing studies, particular emphasis should be placed upon this aspect of brown shrimp life history.

WHITE SHRIMP DISTRIBUTION AND SPAWNING

Although white shrimp along the Texas coast may spawn from late March to early November, peak spawning usually occurs in June or July (Lindner and Anderson 1956). Baxter and Renfro (1966) found that the seasonal abundance of white shrimp postlarvae in the Galveston entrance was characterized by two summer peaks and that the relative strengths of the peaks varied among years. Perez Farfante (1969) reported that white shrimp move from the estuaries to the sea at modal lengths between 100 and 120 mm total length. Pullen and Trent (1966) stated that white shrimp emigrations from Texas bays occurred from October through December, with peaks associated with sharp drops in water temperature. Others (Anderson 1956, Joyce 1965) have noted that maturation of gonads, along with fall and winter temperatures is a principal factor resulting in emigration of white shrimp from estuaries.

TABLE 7. NUMBER AND PERCENT OF WHITE SHRIMP TRAWLED FROM BLOCKS B AND C, INTENSIVE SAMPLING PROGRAM, OCTOBER 1970-SEPTEMBER 1980. NONE WERE TRAWLED FROM BLOCK A

Row	Number	% *	Row	Number	%
B1-B3	507	83	C1-C3	402	82
B4-B6	88	14	C4-C6	57	12
B7-B9	16	3	C7-C9	31	6
B1-B9	611	100	C1-C9	490	100

*Percent of total white shrimp catch in respective block.

Results of factorial analysis of variance performed on the transformed abundance data ($\log_e [n+1]$) showed significant differences among stations, seasons and cruises, and a significant cruise/station interaction term, as shown in Table 8.

TABLE 8. RESULTS OF ANOVA PERFORMED ON TRANSFORMED WHITE SHRIMP ABUNDANCE DATA

Source	df	Sum of Squares	Mean Square	F Value
Total	566	11.95		
Station	26	57.81	2.223	50.97**
Cruise	6	3.91	0.652	14.96**
Station x Cruise	156	33.73	0.216	4.96**
Residual	378	16.49	0.043	

**Significant at the 1% level.

The primary differences in spatial distribution were addressed above--the shrimp were mainly distributed along the shoreline of near-shore blocks. In addition, white shrimp were more abundant and showed more seasonal variation in block B than was observed in block C (Fig. 15). Block C catches totaled 177 shrimp in October, but thereafter, abundance was typically low, ranging from 15 to 69. The catch data showed little evidence of any seasonal immigration from other areas. With the exception of a slight drop in mean length in June 1980, mean length of white shrimp in block C increased from October 1979 through July-August 1980, and declined the following month. Females averaged larger than males (Fig. 15).

Abundance of white shrimp in block B catches dropped from 545 in October 1979 to 291 in February 1980, and to a low of 31 specimens in May 1980 (Fig. 15). Thereafter, abundance increased through August, but sharply declined from 250 in August to 92 in September. Size of shrimp increased from October 1979 through July 1980, dropped sharply in August, and increased again in September (Fig. 15).

Results of the independent histological examination showed that we were quite successful in determining the stage of maturity of adult white shrimp based upon external examination. We correctly identified 100%

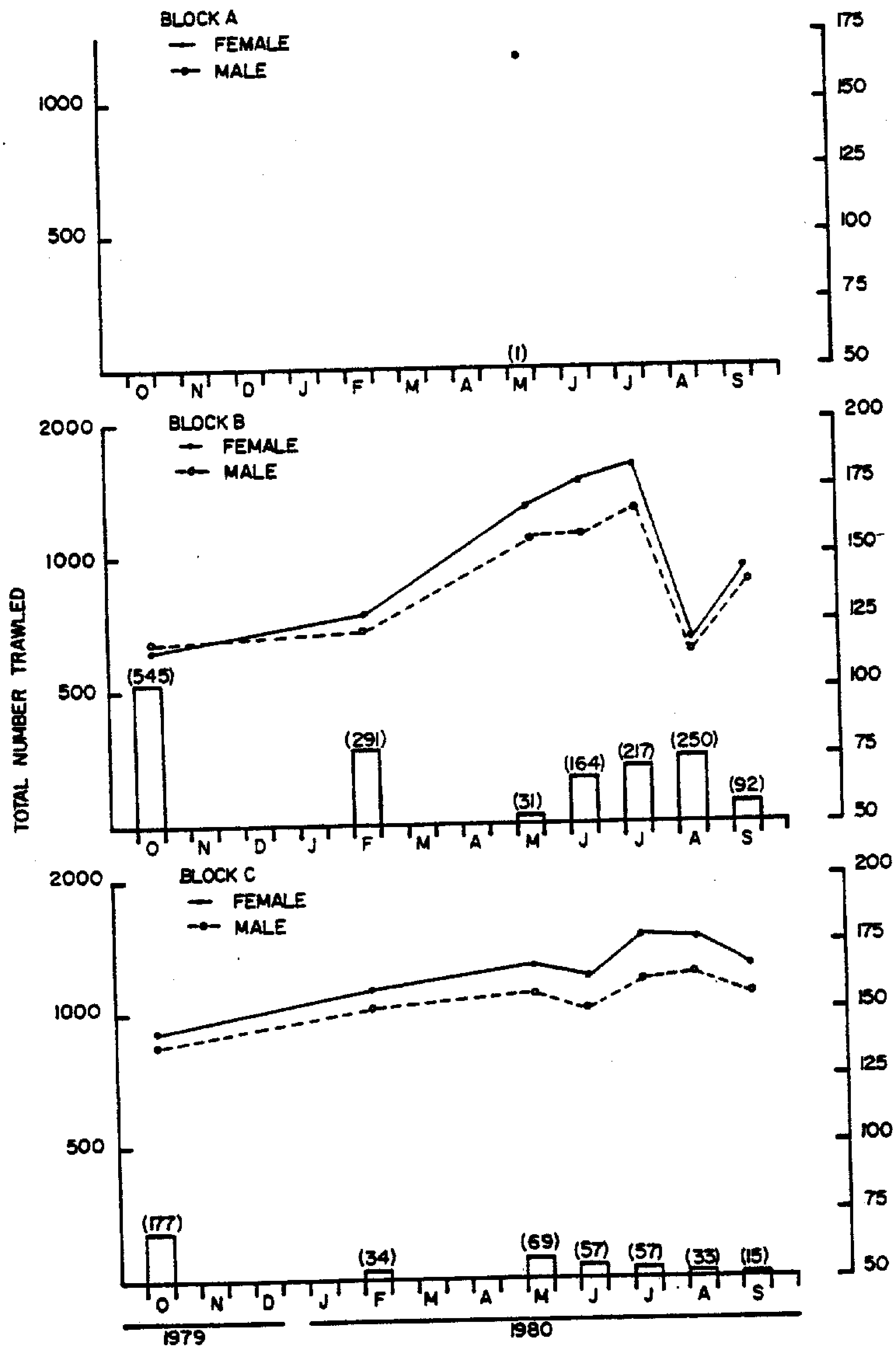

Fig. 15. Number of white shrimp trawled in search and survey effort, by block and month (vertical bars, left axis); and mean total length by sex, block and month (lines, right axis).

of stage 3 and 4 females as well as all stage 2 mature males submitted for histological verification. For immature females, 56% of stage 2 specimens were correctly identified, 44% should have been classified as stage 3. Similar results were obtained for stage 1 females--53% were correct, 42% were actually stage 2 and 5% were stage 3. For shrimp which we classified as immature males, 9 of 10 were correctly identified.

We used stage 3 and 4 white shrimp to represent spawning individuals regardless of whether or not a spermatophore was attached. It has been the practice of mariculture researchers collecting gravid females to retain only white shrimp females with spermatophore when seeking fertilized eggs for culture purposes. In contrast to brown shrimp (thelycum closed, mating occurs just after the female molts, the eggs are fertilized and the spermatophore is not carried until spawning, which may be several days later), white shrimp have an open thelycum and carry the spermatophore from the time of mating to the time of spawning, which is believed to occur on the same day as the mating. Thus, while it would seem an easy task to identify spawning female white shrimp (a specimen with an attached spermatophore), the spermatophore is easily dislodged and is apparently seldom retained by trawled shrimp. Based upon evidence provided by A.L. Lawrence (pers. comm.) from culture experiments, the presence of stage 4 females is adequate evidence for assuming spawning is taking place (or will very shortly take place). This stage persists for only three days, and up to one-third of stage 4 females taken without a spermatophore actually release fertilized eggs on the first night of capture. None kept in isolation produce fertilized eggs thereafter. However, culture research has shown that the eggs will be released by the females--fertilized or not--on their third day in stage 4 condition (A.L. Lawrence, pers. comm.).

Based upon Lindner and Anderson (1956), the maximum distance a white shrimp could travel in three days is about 14 km. Assuming that stage 3 is probably also of short duration, and, given the above, it seems logical that the presence of a stage 3 or 4 female white shrimp would signify imminent spawning within a 14+ km radius.

A total of 204 spawning white shrimp females were trawled, 143 in block B, and 61 in block C (Table 9). A total of 132 of the 143 taken in block B were captured in the inner row of subblocks--three and eight specimens were taken from the middle and outer rows, respectively. Although they were less abundant, a similar pattern was evidenced for spawning white shrimp at block C, where 49, 5 and 7 were taken in the inner, middle and outer rows, respectively. Spawning shrimp were taken in block B during October 1979 and from May through September 7, 1980. These data show a pronounced peak occurring during June and July in block B. Spawning condition females in block C were taken from May-September 1980, and stage 3-4 females were most abundant during May (Table 9).

Female white shrimp of a size capable of attaining sexual maturity were present in each of blocks B and C during October 1979 and February 1980, but only one mature shrimp (October 1979, block B) was represented in the total catch of 138 large females captured during these months

TABLE 9. NUMBERS OF SPAWNING FEMALE WHITE SHRIMP IN BLOCKS B AND C, OCTOBER 1979-SEPTEMBER 1980

	BLOCK B												
ROW:	INNER				MIDDLE				OUTER				Grand
STATION:	B1	B2	B3	Total	B4	B5	B6	Total	B7	B8	B9	Total	Total
Cruise													
Oct-Nov	0	1	0	1	0	0	0	0	0	0	0	0	1
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	3	1	4	0	0	0	0	0	0	0	0	4
June	35	17	12	64	0	3	0	3	0	0	0	0	67
July	8	11	43	62	0	0	0	0	0	0	0	0	62
Aug	0	0	1	1	0	0	0	0	2	0	1	3	4
Sept	0	0	0	0	0	0	0	0	1	2	2	5	5
TOTALS	43	32	57	132	0	3	0	3	3	2	3	8	143

	BLOCK C												
ROW:	INNER				MIDDLE				OUTER				Grand
STATION:	C1	C2	C3	Total	C4	C5	C6	Total	C7	C8	C9	Total	Total
Cruise													
Oct-Nov	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0
May	12	8	5	25	0	0	0	0	0	0	0	0	25
June	0	10	1	11	0	1	0	1	0	0	0	0	12
July	6	5	0	11	0	0	0	0	0	0	0	0	11
Aug	0	1	1	2	1	1	1	3	0	2	5	7	12
Sept	0	0	0	0	0	1	0	1	0	0	0	0	1
TOTALS	18	24	7	49	1	3	1	5	0	2	5	7	61

(Fig. 16). Pronounced spawning activity in block B occurred during June and July when a high proportion (70 and 62%) of a relatively large population of adult females was in spawning condition. Number of adult-sized, female white shrimp declined markedly after July, and only one one occasion were as many as 50% sexually mature. Number of adult females and the proportion sexually mature were greatest in May in the more southerly block C (Fig. 16). Abundance of adults and proportion of mature females in block C declined after May, except during August when high proportions of small numbers of adults were mature.

The various gonad/hepatopancreas ratios are shown by Fig. 16. As was the case for brown shrimp the indices based upon dry weights and percent lipids agreed well with determinations of the reproductive state of the population based upon external examination. However, the indices based upon percent carbohydrates and percent protein yielded little information useful for assessing the maturity state of the individuals examined.

A total of 309 mature white shrimp males were trawled, 194 in block B and 115 in block C (Table 10). As with females, the vast majority were taken from the inner row of subblocks (177 of 194 trawled in block B, 99 of 115 in block C). Mature males were not represented in either of blocks B or C during October-November 1979 or February 1980, but were in each block on every trip May-September 1980. In block B, abundance of mature males was greatest in June and July (particularly July) whereas mature males in block C were most abundant during May-July (Table 10). The observed patterns of abundance for mature males approximated very closely with that observed for female white shrimp in a spawning state.

Male white shrimp of a size capable of being mature were represented in blocks B and C during each month sampled (Fig. 17) and none was taken in block A. In each of blocks B and C, the highest proportions of adult males in a mature state occurred during the same months that the highest proportions of adult females were in spawning condition (Figs. 16 and 17). However, the proportion of adult males actually mature during these months was markedly greater than the proportion of adult females in spawning condition. This strategy would seem to insure that any adult males encountered by females while in their short-lived spawning condition would be capable of completing the reproductive cycle.

The various gonad/hepatopancreas ratios for white shrimp are shown by Fig. 18. As was the case for brown shrimp the indices based upon dry weights and percent lipids agreed well with determinations of the reproductive state of the population based upon external examination. However, the indices based upon percent carbohydrates and percent protein yielded little information useful for assessing the maturity state of the individuals examined.

A total of 12 stage 4 white shrimp were spawned on board the vessel during 1980; four were spawned in May, one in June, six in July; one during August, and one in September. In May, all were taken from block B, and ranged in total length from 150-170 mm. Estimated number of eggs released per female collected in May ranged from 72,600-206,800

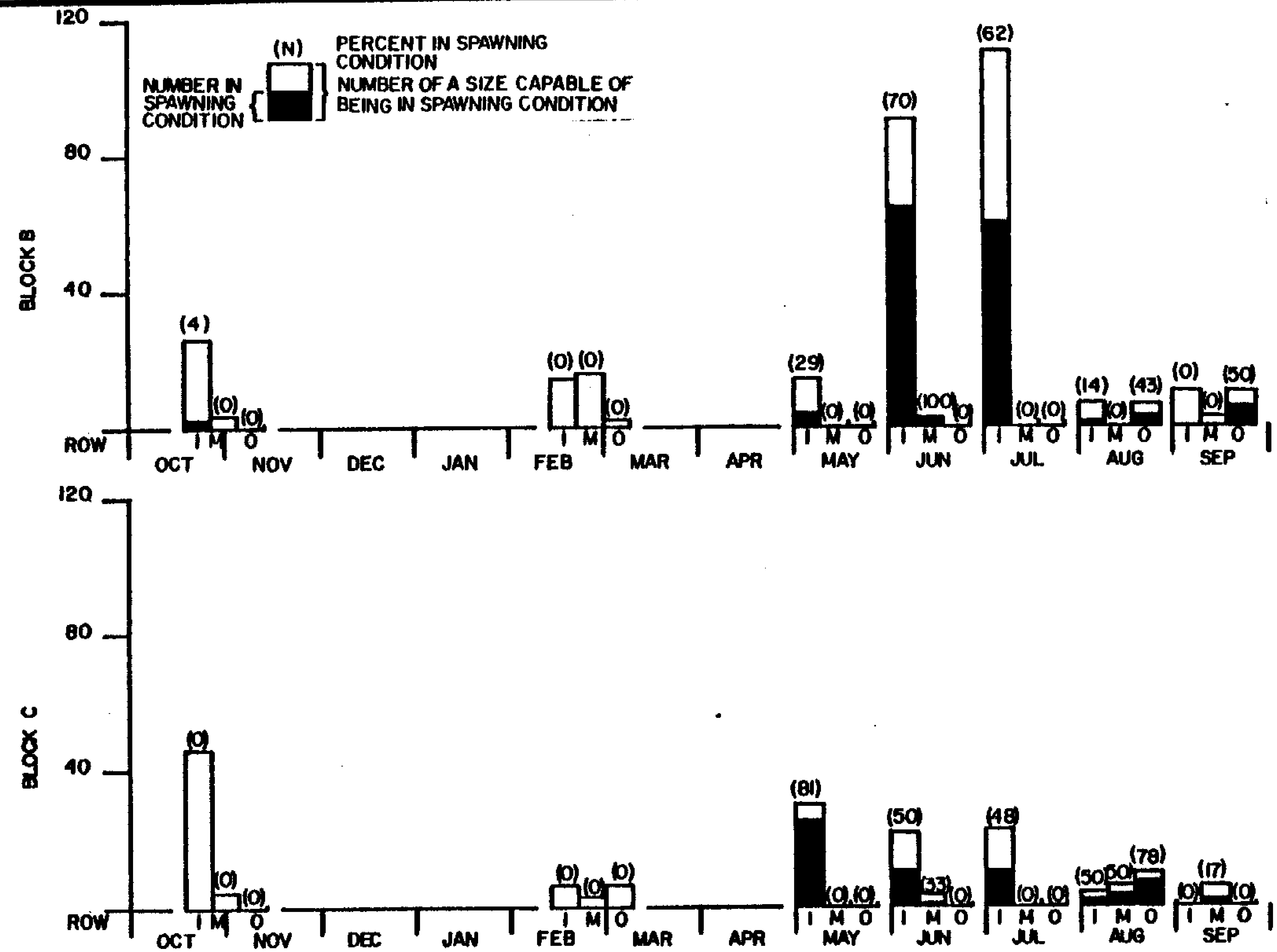

Fig. 16. Total number of white shrimp females in spawning size classes (entire bar) and proportion of those actually in spawning condition (shaded bars, % in parenthesis), by month and block.

TABLE 10. NUMBERS OF MATURE MALE WHITE SHRIMP IN BLOCKS B AND C, OCTOBER 1979-SEPTEMBER 1980

	BLOCK B												
ROW:	INNER				MIDDLE				OUTER				Grand
STATION:	B1	B2	B3	Total	B4	B5	B6	Total	B7	B8	B9	Total	Total
Cruise													
Oct-Nov	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	7	4	11	0	0	0	0	0	0	0	0	11
June	24	15	19	58	0	5	0	5	0	0	0	0	63
July	15	16	73	104	0	0	0	0	0	0	0	0	104
Aug	0	1	0	1	0	0	0	0	1	3	0	4	5
Sept	0	0	3	3	0	0	0	0	0	4	4	8	11
TOTALS	39	39	99	177	0	5	0	5	1	7	4	12	194

	BLOCK C												
ROW:	INNER				MIDDLE				OUTER				Grand
STATION:	C1	C2	C3	Total	C4	C5	C6	Total	C7	C8	C9	Total	Total
Cruise													
Oct-Nov	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0
May	16	11	9	36	0	0	0	0	0	0	0	0	36
June	0	18	12	30	0	1	1	2	0	0	0	0	32
July	11	17	0	28	0	0	0	0	0	0	0	0	28
Aug	0	3	2	5	1	1	0	2	2	3	0	5	12
Sept	0	0	0	0	3	3	0	6	1	0	0	1	7
TOTALS	27	49	23	99	4	5	1	10	3	3	0	6	115

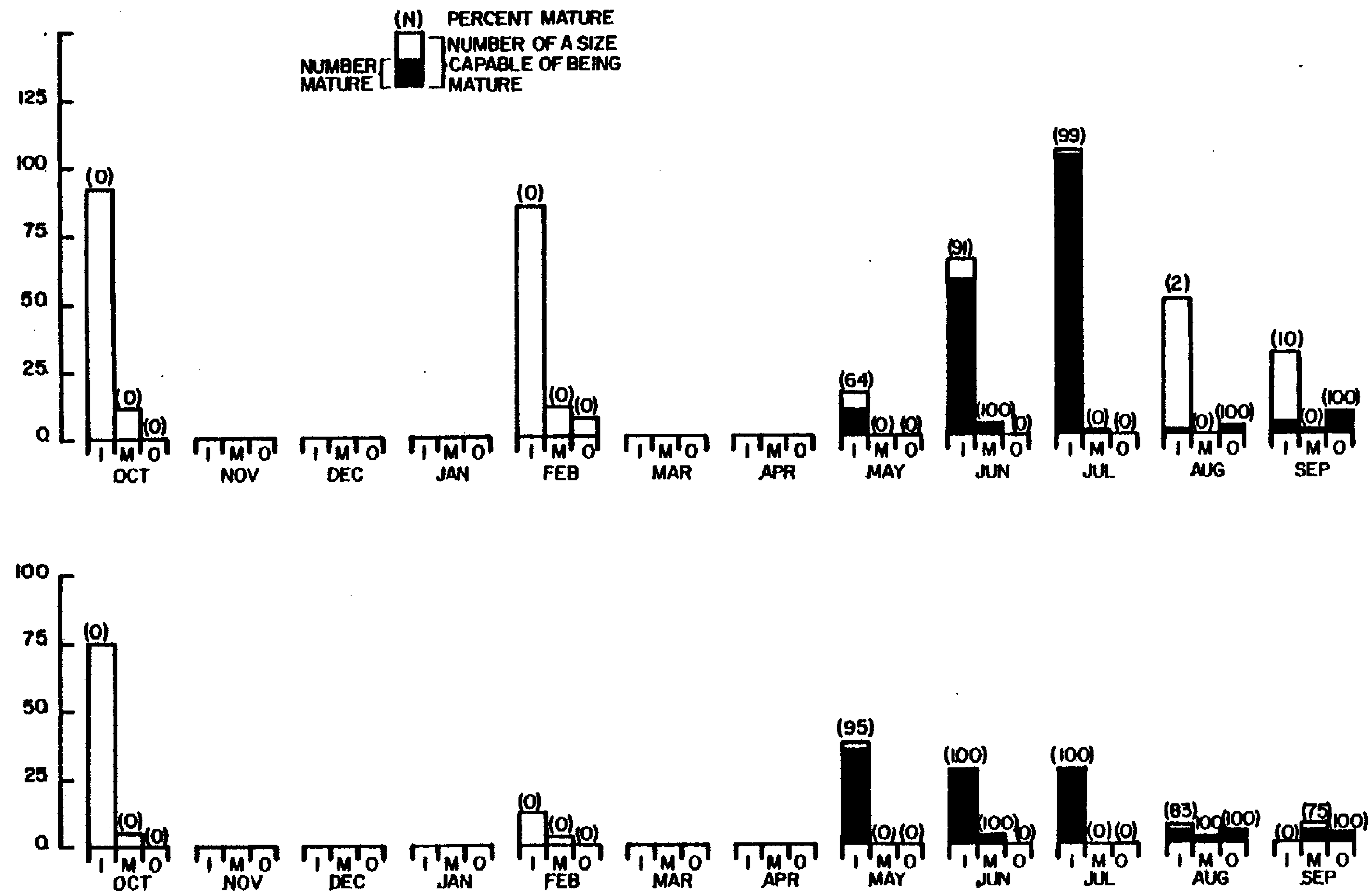

Fig. 17. Total number of white shrimp males of a size capable of maturity (entire bar) and proportion of those actually mature (shaded part of bar, % in parenthesis) by month for block A.

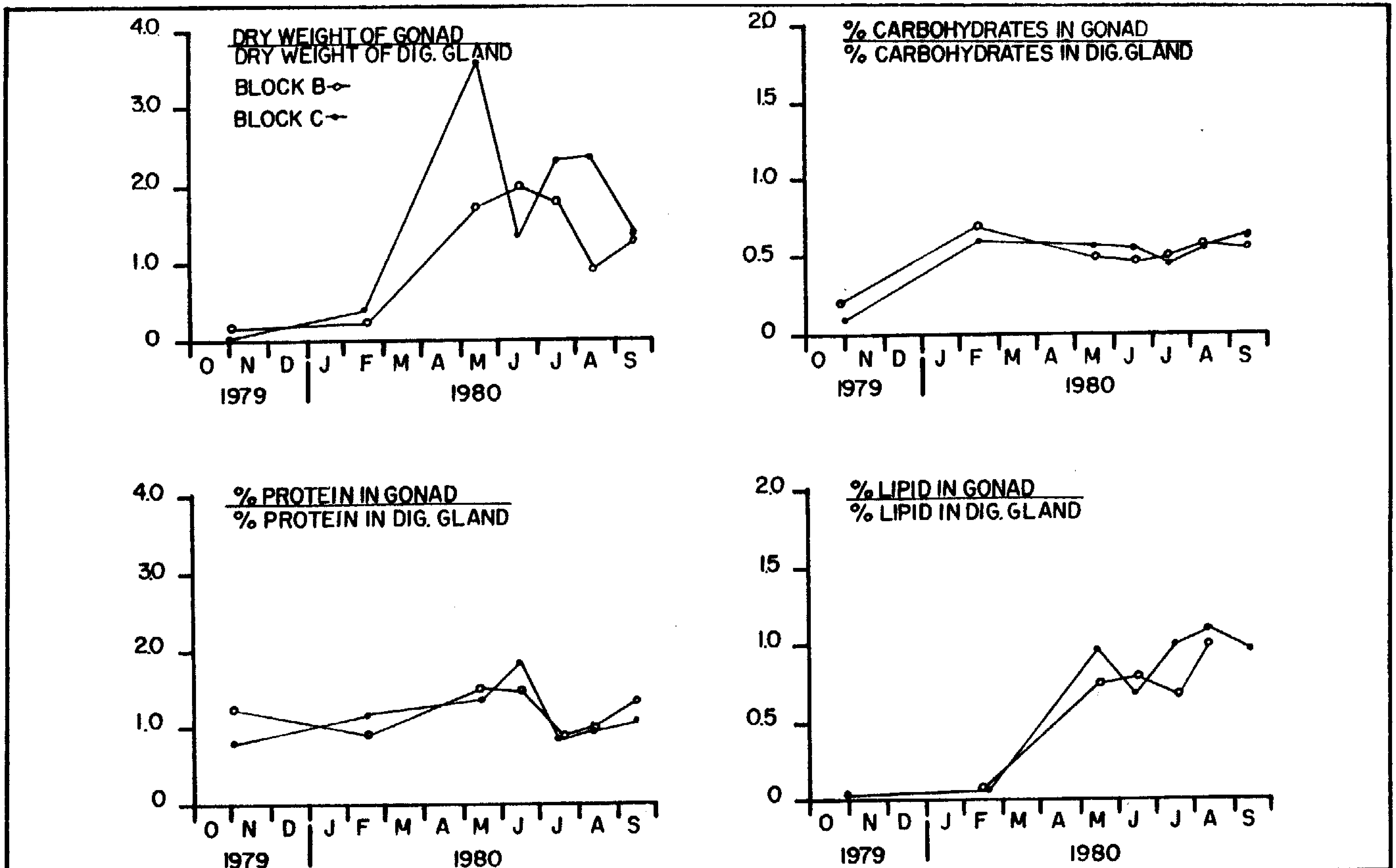

Fig. 18. Ratios of various measures of female white shrimp maturation indicators in gonads versus digestive glands, by month and block.

and averaged 147,950. In June, a single female 175 mm in total length taken from block C produced 413,600 eggs. In July, six females (two from block B and four from block C) ranged in total length from 181-192 mm, and produced an average of 269,500 eggs (range 195,800-369,600). In August, one female from block C, 194 mm long, produced 510,000 eggs. In September, one female from block C, 165 mm in total length, produced 15,000 eggs. In contrast to brown shrimp, egg number and female total length were highly correlated over the course of the study ($P < .01$).

None of the eggs from females collected in May were viable in our culture tanks on board. Naupliar survival in June was 68.8%, protozoeal survival was 73.9% (the error in the estimation method is about ± 10-20%--hence the apparent and obviously incorrect increase).

The July figures for naupliar and protozoeal survival averaged 52.3 and 50%, respectively. In August the single female collected yielded eggs whose naupliar and protozoeal survival were 53 and 57%, respectively. Corresponding figures for the only mature white female collected in September were 25% and 25%. Survival from the naupliar to protozoeal stages thus appeared to be very good with no detectable decrease in survival between stages. The data for white shrimp survival from nauplii to protozoea were not collected since the vessel had to be vacated at the end of cruise 7 before enough time had elapsed for the larvae to reach the protozoeal stage.

Of the original concerns about the previously proposed 5-mi diffuser site, the one related to the possibility that the area might represent a white shrimp spawning area has proven well-founded. Results of our sampling program showed that white shrimp females in spawning condition (and white shrimp in general) are generally restricted to the area from the beach out to 8 km (5 mi), but their abundance declined rapidly with greater distance offshore. The present location of the diffuser (19 km or 12 mi offshore) should pose little threat to white shrimp spawning activities. In contrast to the level of uncertainty concerning the impact of brine disposal on brown shrimp larvae and postlarvae, we can foresee little or no impact of brine disposal at the 12-mi site on white shrimp larvae and postlarvae. Peak immigration of these forms into the estuary probably occurs very soon after spawning which appears restricted to nearshore zones.

ABUNDANCE AND DISTRIBUTION OF REPRODUCTIVE PRODUCTS

Benthic Grab Samples

Each of three sediment grab samples taken at the intensively sampled sites for cruises 1 (Ekman grab sampler) and 2 (Ponar sampler) (Total = 54 "grabs") were analyzed for penaeid eggs. No eggs were found which resembled reference specimens obtained from the spawns of captive females. No *Penaeus* eggs were expected to be found during these seasons (October/November, February/March) at blocks B and C which were located primarily in white shrimp habitat, but eggs were expected to occur during these periods in block A which was located in brown shrimp habitat. The failure to collect eggs in these samples may have been because the sample size was not large enough (total 0.3 m^2) or that the eggs were pushed away from the sample locations by a pressure wave generated by the descending grab. If large numbers of eggs had been present, at least some should have been obtained . However, it seems probable that few or no eggs were in the areas sampled. The flotation technique which was utilized in the laboratory to separate the eggs from other sediment samples successfully sorted many eggs from the samples, and appeared to work very well. Even so, a shrimp egg is very small (0.28 mm diameter) and conceivably could have been lost in processing.

Benthic Sled Samples

A total of 27 sites were sampled during February 1980 with a benthic sled having a 1.3 mm mesh to determine whether or not overwintering postlarval brown shrimp were in the study area. While a variety of benthic invertebrates (ranging from polychaetes to mysids) were collected, no postlarval *Penaeus* were taken. We do not believe that this information discounts the hypothesis that brown shrimp postlarvae spawned in fall, overwinter in the sediment during winter, and emerge and enter the estuaries during early spring. The evidence of Aldrich et al. (1968) that burrowing is a behavioral response of postlarval brown shrimp to low temperature is persuasive. If one interprets the lack of or low abundance of postlarvae in the sediments indicate the absence of burrowing, it is extremely difficult to account for the source of the major peak of postlarval brown shrimp coming into Texas estuaries during the spring. We believe it likely that brown shrimp postlarvae burrow into the substrate at the point they have reached in their shoreward migration when water temperature becomes unfavorable. In any case, it may not be probable that a major portion of overwintering brown shrimp postlarvae will be affected by the discharge of brine at the 12-mi diffuser site (no evidence of concentration at the site was found), but this has not been demonstrated with certainty.

Gulf V Plankton Samples

A Gulf V plankton sampler having a mesh size of 0.20 mm was deployed for three bottom tows at nine stations over the five-month period May-September 1980, yielding a total of 135 samples. The estimated targets of this sampling device were penaeid eggs, nauplii and protozoea. Eggs resembling reference specimens obtained from penaeid shrimp spawned on the vessel were taken only during a single month (May), with 280 collected at subblock B3 and 40 taken at subblock B5. During this month, white shrimp in spawning condition were present in block B and four specimens with spermatophores attached were taken in the intensive sampling effort. These specimens spawned on the vessel, but did not produce viable eggs. This may have been due to the fact that no ethylenedinitrib tetraacetic acid (EDTA) or antibotics were added to the water in which the shrimp spawned , since EDTA and antibotics have been shown to increase hatching success and survival of larvae (A.L. Lawrence, pers. comm.)

The paucity of penaeid-type eggs was unexpected--they should seemingly be abundant along the bottom during periods of intense spawning. The Gulf V may not get close enough to the bottom to effectively sample the eggs or we may have sampled at the wrong time of day to obtain eggs. We sampled at night in block A and within four hours of sunset at inshore blocks B and C. Captured shrimp which were spawned on the vessel released their eggs at about 0200-0300 hours, and Mock (1972) has reported that brown shrimp spawned in the laboratory released eggs around midnight and that the eggs hatch about nine hours later. If shrimp in their natural environment spawn at similar times, the eggs, in many cases, would be hatched prior to our sampling effort in the evening, and therefore would never appear in our collections.

Penaeid nauplii were collected in the Gulf V sampler during June-September 1980, as indicated in Table 11.

TABLE 11. TOTAL NUMBERS OF PENAEID NAUPLII COLLECTED BY THREE REPLICATE TOWS OF THE GULF V NET, JUNE-SEPTEMBER 1980

		Cruise (1980)			
Block	Row	June	July	August	September
A	I	-	-	320	40
A	M	-	-	160	63
A	O	-	-	60	40
B	I	40	-	-	-
B	M	200	300	60	-
B	O	380	360	100	200
C	I	80	1240	20	40
C	M	440	-	40	80
C	O	20	20	-	20

Nauplii of the family Penaeidae were represented and were abundant in block A during August and September, which are the peak brown shrimp spawning months. In blocks B and C, they were well represented during each of these four months but were particularly abundant during June and July which generally coincides with peak white shrimp spawning. With the exception of the 1,240 specimens taken in the inshore row of block C, the spatial distribution of nauplii did not match well with that observed for spawning white shrimp.

Protozoea were scarce during May through July 1980--one was taken in block C during May, eight were taken there during June, and none were collected at any station in June (Table 12).

TABLE 12. TOTAL NUMBERS OF PENAEID PROTOZOEA COLLECTED BY THREE REPLICATE TOWS OF THE GULF V NET, JUNE-SEPTEMBER 1980

		Cruise (1980)				
Block	Row	May	June	July	August	September
A	I	-	-	-	58	80
A	M	-	-	-	115	40
A	O	-	-	-	278	-
B	I	-	-	-	-	-
B	M	-	-	-	-	-
B	O	-	-	-	-	-
C	I	-	-	-	-	-
C	M	-	8	-	-	-
C	O	1	-	-	-	-

In August and September, protozoea of the family Penaeidae were indicated to have been abundant in offshore block A. The time and places they were abundant matched well with high brown shrimp spawning activity.

Bongo Net Samples

The primary targets of the bongo net samples were mysis and post-larval stages of the genus *Penaeus*. The number of mysis stage collected by cruise and location are shown in Table 13.

TABLE 13. NUMBER OF *PENAEUS* SP. MYSIS/100 m^3, COLLECTED IN THE BONGO NET DURING MAY-SEPTEMBER 1980

	Cruise (1980)					
Station	May	June	July	August	September	Means
Al	-	-	4.37	7.53	1.40	4.43
AM	-	-	-	19.33	0.53	6.62
AO	-	-	2.90	9.77	2.10	4.92
MEAN	0.00	0.00	2.42	12.21	1.34	15.97
BI	-	1.87	-	-	2.33	1.40
BM	-	-	-	-	-	0.00
BO	-	-	-	-	-	0.00
MEAN	0.00	0.62	0.00	0.00	0.78	1.40
CI	-	-	2.23	1.27	4.03	2.54
CM	-	-	-	4.53	0.93	1.82
CO	-	-	-	1.00	1.87	0.96
MEAN	0.00	0.00	0.78	2.27	2.28	5.29
GRAND MEAN	0.00	0.62	3.17	14.48	4.40	22.67

Mysis stage *Penaeus* sp. were more abundant in August than during any other month when the majority of the total mysis collected during the entire program were taken at block A. The period and location of the peak abundance of the mysis stage coincided with the brown shrimp spawning season and grounds, respectively.

Postlarvae were not taken in the bongo nets during October-November 1979, February 1980 or during May 1980. They were represented in catches from June-September 1980:

TABLE 14. NUMBER OF *PENAEUS* SP. POSTLARVAE/100 m^3, COLLECTED IN THE BONGO NET DURING JUNE-SEPTEMBER 1980

	Cruise (1980)				
Station	June	July	August	September	MEANS
AI	-	5.80	5.90	1.40	4.37
AM	-	1.63	12.03	0.53	4.73
AO	-	7.20	0.66	0.57	2.81
MEAN	0.00	4.88	6.20	0.83	3.97
BI	1.90	2.00	4.93	8.00	5.61
BM	1.33	-	7.10	7.70	5.38
BO	1.83	1.10	-	1.73	1.39
MEAN	1.69	1.03	4.01	5.81	4.18
CI	-	-	7.40	10.07	5.82
CM	5.10	-	1.50	0.93	2.51
CO	-	1.23	1.00	1.87	1.37
MEAN	1.70	0.41	3.30	4.27	3.20
GRAND MEAN	1.13	2.10	4.50	3.64	2.85

Postlarval shrimp increased in abundance from June through August and catches were still high during September 1980. Equivalent numbers were collected from each of blocks A, B and C. In the inshore blocks, postlarvae were more abundant in the inshore rows than in the outermost rows. Results of factorial analysis of variance performed on these data showed that the differences among months were significant.

TABLE 15. RESULTS OF ANOVA PERFORMED ON POSTLARVAE DATA, OCTOBER-NOVEMBER 1979-SEPTEMBER 1980

Source	df	Sum of Squares	Mean Square	F Value
Total	188	34594.21		
Station	8	9512.28	1189.04	0.78
Month	6	56075.31	9345.88	6.11**
Station x Month	48	87600.31	1825.01	1.19
Residual	126	192753.33	1529.79	

**Significant at the 1% level

Data from the bongo net, and particularly from the Gulf V net, show that fewer larvae and postlarvae were collected than would be expected based upon the results of other studies (Heegaard 1953, Temple and Fischer 1967, Baxter and Renfro 1966). The Gulf V plankton sampler utilized in this study was towed just above the surface of the substrate, where Heegaard (1953) reported that larval shrimp were thickest (his identification of some *Penaeus* larval stages appear to have been incorrect--see editors' notes in Heegaard's 1953 report). Temple and Fischer (1965) also found that in a vertically stable water mass the protozoeal stages of penaeid shrimp were collected most often near the bottom. However, they did observe a diurnal vertical migration of penaeid larvae at sunset, during which the bathymetric distribution of each planktonic stage extended to the surface waters. By utilizing an oblique-step tow, Temple and Fischer (1967) captured similar numbers of larval *Penaeus* spp. regardless of the time of day. Thus, our deployment of the Gulf V net just above the bottom should not have been expected to capture large numbers of postlarval *Penaeus*, and its use within four hours of sunset may have resulted in its capturing fewer *Penaeus* larvae than it would have had it been deployed during the day. The bongo net tows were quite short and sampled all strata of the water column equally, capturing penaeid spawning products more consistently than did the Gulf V net.

ENVIRONMENTAL CHARACTERIZATION OF SPAWNING SITES

A major objective of the program was to define shrimp spawning areas and seasons, relating them to environmental attributes. Results presented above in conjunction with the literature show that brown shrimp spawning is greatest in August-October and is characterized by a lesser peak in May-July. Spawning of brown shrimp appears restricted to depths greater than 20 m and is likely to be highest at depths between 40 and 50 m. In contrast to brown shrimp spawning, spawning of white shrimp is greatest during May-July and most spawning takes place within 8 km (5 mi) of the beach. As is always the case, our sampling program was somewhat limited by the amount of resources available to perform the project, and a large suite of environmental variables could not be measured at each station on every trip. In June, a broad array of environmental variables was measured during a period when both species were spawning. These data were subjected to multivariate analyses as described below in an attempt to characterize spawning sites.

The response variables used for the multivariate analyses were:

TABLE 16. ENVIRONMENTAL RESPONSE VARIABLES USED IN MULTIVARIATE ANALYSES

Water

Water depth (m)
Bottom water temperature (°C)
Bottom water conductivity (μmhos/cm)
Bottom water dissolved oxygen (mg/ℓ)

.....cont'd

TABLE 16 (cont'd)

Sediments	Biota ("Shrimp Prey")
Sand (%)	
Silt (%)	
Clay (%)	
Total organic carbon (%)	
Mean particle size (phi)	
Total fatty acid (ppm)	*Total fatty acid (ppm)
*Fatty acid 20:4 (ppm)	*Fatty acid 20:4 (ppm)
*Fatty acid 20:5 (ppm)	Fatty acid 20:5 (ppm)
*Fatty acid 22:6 (ppm)	Fatty acid 22:6 (ppm)
Total sterols (ppm)	Total sterols (ppm)
Total carotenoids (ppm)	Total carotenoids (ppm)

*Characterized by highly skewed and kurtotic distributions

Data for each of the above environmental variables, and the associated shrimp abundance data were available for each of the 27 stations sampled in June 1980.

The initial step in the multivariate analyses was to screen the environmental variables for gross departures from the assumption of normality, a prerequisite for parametric analyses. As indicated by Table 16 , five variables were deleted because they had highly skewed and kurtotic distributions.

The next step was to subject the data to principal components analysis (PCA). The PCA routine used was BMDP4M (Dixon and Brown 1979). The analysis was performed using a correlation matrix without rotation of factors. PCA examines all variables simultaneously and creates an ordered set of new, independent variables, each of which describes progressively less variability. The benefits of PCA are that (1) most of the information content of a large data matrix can be summarized into a much reduced set of factors, (2) the effects of correlations of original variables can be eliminated by using the reduced set of independent factors in subsequent analyses and (3) plotting of original samples onto the frame of reference defined by the reduced factors frequently reveals natural groupings that may be useful for detecting response to the gradients described by the reduced factors, or that may be useful for classification. Examination of the correlation of original variables with the reduced factors frequently permits identification of the major underlying sources of variation.

PCA produces as many factors as variables in the original matrix. We used only the major factors identified by the PCA (those having an eigenvalue > 1) as inputs for a cluster analysis using the factor scores as variables. The cluster alogorithm used (BMDP2M, Dixon and Brown 1979) was based on Euclidian distances. This approach successively amalgamates samples to form larger groups using a measure of average distance.

In an attempt to elucidate the variables to which spawning shrimp appeared to respond to in June, we used a stepwise multiple linear regression approach using BMDP2R (Dixon and Brown 1979). In these analyses, the number of spawning female shrimp was used as the dependent variable. Additional variables to be entered into the regression model were chosen using a F-to-enter criterion (see Dixon and Brown 1979). For our analyses, the F-to-enter threshold was set at 3.39.

Discriminant function analysis (DFA) was used to identify the major differences between stations having spawning shrimp in June and those which did not have spawning shrimp. The DFA used was BMDP7M (Dixon and Brown 1979) which is a stepwise version. Stepwise DFA involves computation of a discriminant function starting with one variable, and sequentially adding additional variables until the best discrimination between the groups has been achieved. The results of each of the above analyses are described below, and are followed by a summary discussion.

Principal Component Analysis

Five factors accounting for 85% of the total variance of the original data matrix were examined. The loadings (correlations) of the original variables on these factors are listed in Table 17. In general the factors represent:

factor 1 - a contrast; substrate texture (and associated biochemistry) and temperature *vs* conductivity and depth

factor 2 - a contrast; depth, and fatty acid 20:5 in biota *vs* temperature

factor 3 - a contrast; substrate carotenoids *vs* dissolved oxygen

factor 4 - levels of fatty acid 22:6 in biota, and carotenoids

factor 5 - levels of biota sterols, and silt

Based upon factors 1 and 2, sites from block A separated clearly from sites from blocks B and C (Fig. 19). Little pattern is evident with respect to the distribution of spawning brown shrimp which were represented throughout the block A cluster. No well-defined patterns are evident for groups of other sites (blocks B and C), nor does there appear to be a relationship between the presence of spawning white shrimp and factor scores. What these data indicate is that brown shrimp characteristically spawn in deeper, more-saline offshore waters and white shrimp spawn in shallow, less-saline nearshore waters. Within each of these areas, none of the sites clustered together in a unique fashion correlated with the presence of spawning adults of either species. Based upon the variables we measured, this analysis provided no evidence supporting the concept of "spawning sites" *per se*.

TABLE 17. LOADINGS OF ORIGINAL VARIABLES ON FIRST FIVE FACTORS. LOADINGS LESS THAN 0.25 ARE OMITTED FOR CLARITY.

	Factor				
	1	2	3	4	5
Total organic carbon	0.840	0.324	-	-	-
Mean particle size	-0.820	0.425	-	-	0.258
Sediment sterol	0.796	-	0.308	-	-0.255
% clay	0.793	0.432	-	-	-
Sediment fatty acid (Total)	0.742	-	-	-	0.262
Temperature	0.737	-0.584	-	-	-
Conductivity	-0.728	0.379	0.480	-	-
Depth	-0.679	0.592	0.269	-	0.260
% silt	0.627	-	0.353	-	0.464
Biota fatty acid 20:5	0.548	0.543	-	0.463	-
Sediment carotenoid	0.574	-	0.737	-	-
Dissolved oxygen	-0.431	0.387	-0.533	-	0.252
Biota fatty acid 22:6	0.344	0.385	-	0.725	-
Biota carotenoid	-0.339	-0.290	0.316	0.700	0.295
Biota sterol	0.451	-0.369	-	0.404	0.494
% Variance Explained	42.4	14.4	11.2	10.1	6.9

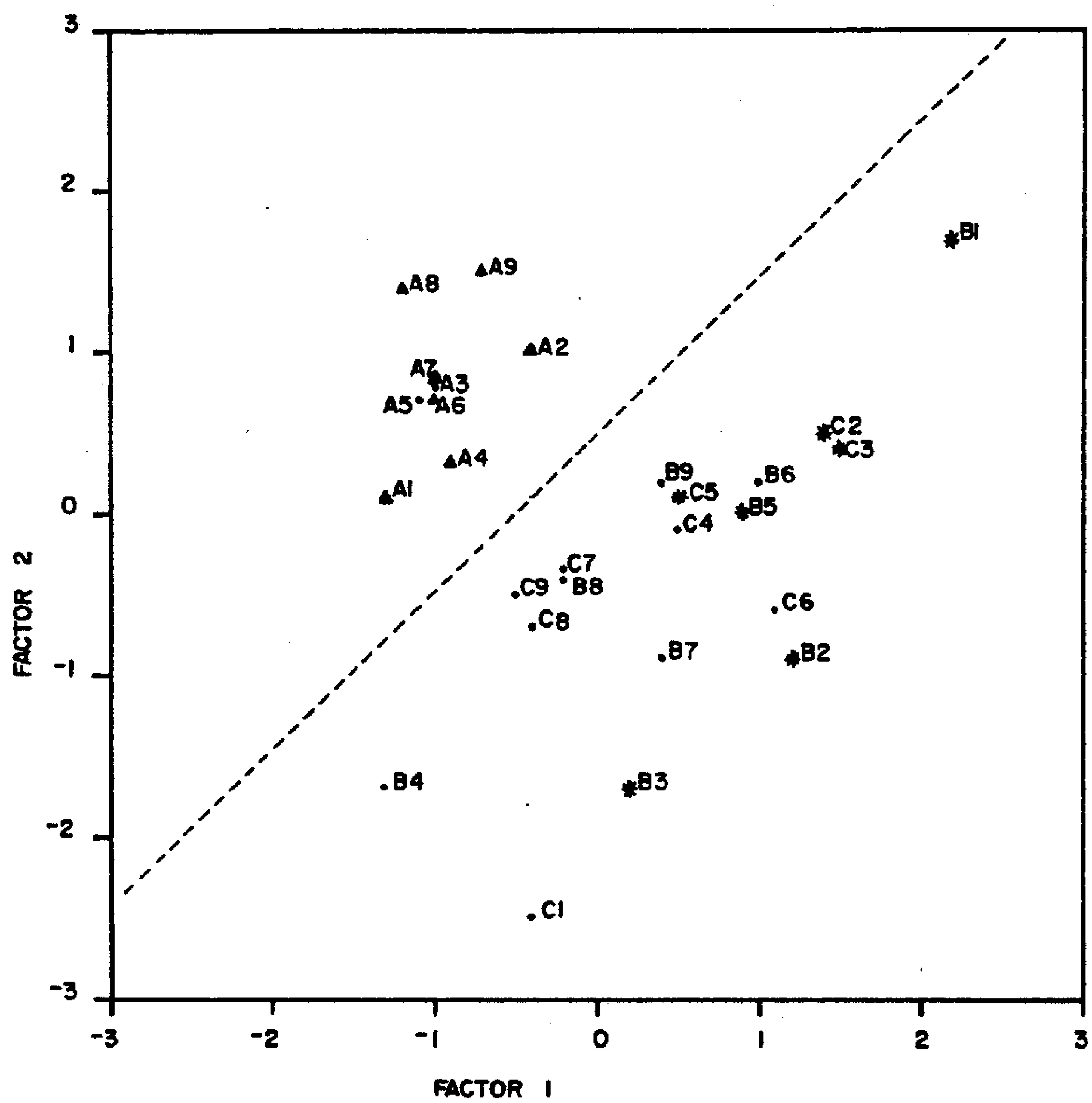

Fig. 19. Scatter diagram showing the distribution of sample sites along factors 1 and 2. Sites marked (*) are locations at which spawning female white shrimp were collected and sites marked (▲) are sites where spawning female brown shrimp were taken.

Cluster Analysis

The cluster analysis summarized the grouping of sample sites as they were distributed in the 5-dimensional space defined by principal component analysis (Fig. 20). There is little evidence of well-defined clusters of locations, although most of the 'A' sites group together and typically contained spawning brown shrimp. There is extensive overlap in the distributions of 'B' and 'C' sites, and no pattern in relation to presumed spawning areas of white shrimp. As with the principal components analysis, results of the cluster analysis provided no evidence for "spawning sites" *per se*.

Multiple Linear Regression

The results for white and brown shrimp were quite different in terms of number and actual variables that seem to determine shrimp spawning distribution. For white shrimp, the analysis proceeded for five steps; the variables included were conductivity (40.8) , concentration of 20:5 fatty acids in the biota (12.2), temperature (7.7), dissolved oxygen (6.1) and sediment sterols (4.1). The preceeding numbers in parentheses give a measure of the relative importance of the variables in explaining the abundance of spawning shrimp.

The analysis for brown shrimp proceeded for only two steps. The variables used were temperature (23.6) and biota sterols (3.7). Details of the regressions and fit with observed values are shown by Table 18 which includes probability levels. Since variables were selected for inclusion in the regression by their F-values, the significance of the regression line cannot be determined by comparison of F-values to the F-distribution. The probability levels presented here are not to be taken literally; they merely indicate a relatively good fit of the abundance of shrimp as predicted by the regression model and as compared to what was actually measured.

TABLE 18. REGRESSION STATISTICS

	R-Square	F	df	P
White shrimp	0.89	35.72	5,21	<<0.001
Brown shrimp	0.50	12.11	2,24	<0.001

If a variable did not enter into the analysis it cannot be concluded that it was unimportant; it may have just been correlated with another variable already in the equation. For example, brown shrimp abundance is correlated with depth; however, depth is highly correlated with temperature ($r = -0.919$, $p < 0.01$) hence, one but not both variables entered into the regression model.

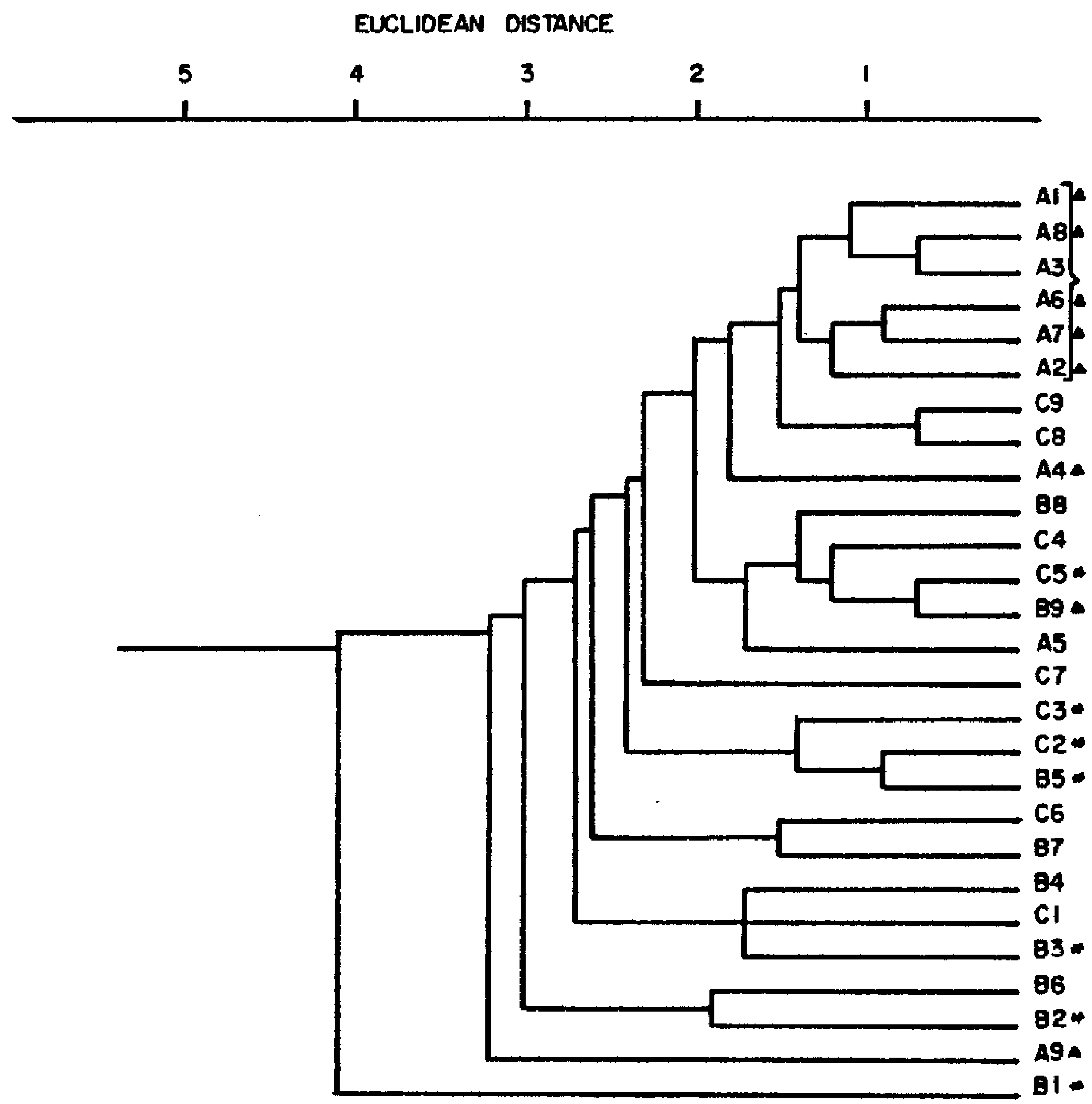

Fig. 20. Dendogram showing similarities of sample locations based on scores of first five factors generated by principal component analysis. Sites marked (*) are locations at which mature white shrimp were collected and sites marked (▲) are sites where spawning female brown shrimp were taken.

Discriminant Function Analysis

The DFA proceeded four steps (using an F-to-enter of 4.0) yielding a function that could discriminate with 100% success between sites in blocks B and C with and without spawning white shrimp. This difference is highly significant ($F_{[4,13]} = 26.62$, $p < 0.001$). The variables included in the function in order of their decreasing importance were sediment sterols, total organic carbon, biota carotenoids and mean particle size. The concentration of sediment sterols by itself was significantly different (t-test $p < 0.001$) between the two groups. The locations of the sample sites along the gradient represented by sediment sterols and the discriminant function are shown in Fig. 21.

Discussion

In our sample units, brown shrimp spawn almost exclusively in block A. Along factors 1 and 2 (Fig. 17), block A formed a distinct cluster. From the factor loading, it can be inferred that block A differs from the other blocks primarily with respect to temperature and depth. The regression analysis also implicated temperature as the primary variable in determining abundance of brown shrimp spawners. Without having sampled at intermediate areas (between blocks A and B) we cannot describe a detailed relationship between spawning abundance and temperature; however, it is likely that spawning brown shrimp are rather broadly distributed in offshore areas.

White shrimp spawning areas remain difficult to describe. The factor (PCA) and cluster analysis were unsuccesful in elucidating any trends that reflect white shrimp spawning abundance. This may be a function of the inclusion of variables that dominate the analyses but that are irrelevant to the elucidation of the question we are asking. As we further investigate the relationships between the variables measured and shrimp distributions (and include more samples) the methods used here will probably prove more successful. The regression analysis of white shrimp spawning abundance did identify several variables of probable importance.

In contrast to spawning brown shrimp which appeared uniformly distributed in low levels of abundance, white shrimp in spawning condition tended to be patchily distributed; i.e., either present in moderately large numbers or absent. One interpretation of this type of distribution is that white shrimp may have very precise requirements for spawning. We believe that the approach being used may delimit these requirements upon the acquisition of more sample variables. The results of the discriminant analysis have already shown that areas with white shrimp in spawning condition differ significantly from areas without mature females in terms of the physical nature of the sediments, the sediment biochemistry and the sterol concentrations in prey organisms. The sterol level in the sediments was implicated as being of primary importance. The analysis of more samples and, in particular, of the relationship between changes in sediment characteristics and abundance of spawning shrimp over time can be used to test these preliminary results.

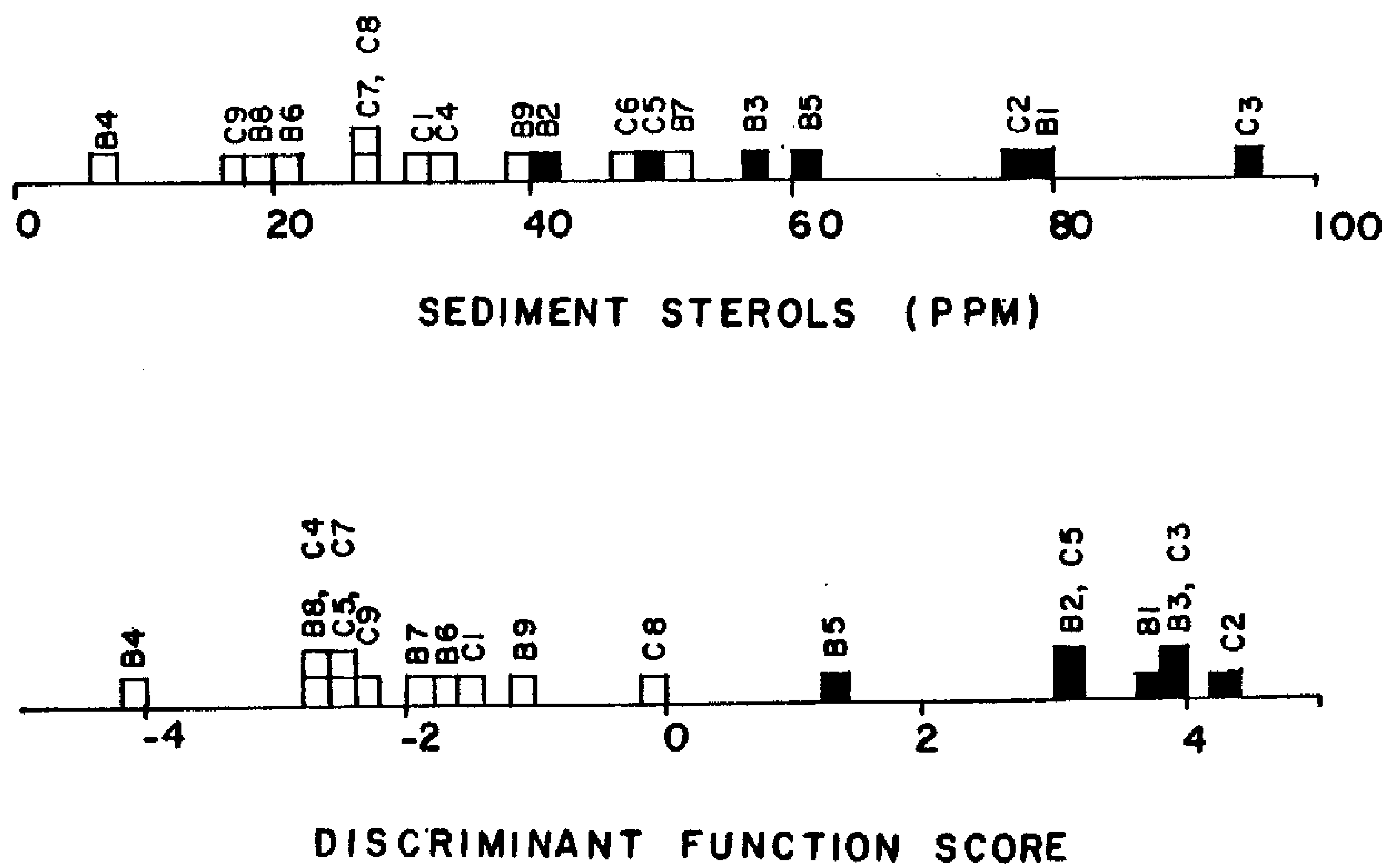

Fig. 21. Distribution of sample locations along the gradients representing sediment sterols (upper figure) and the discriminant axis maximizing the differences between samples with and without mature female white shrimp (lower figure). The samples represented by solid blocks had mature female white shrimp, those with open blocks did not.

SECTION 5

LITERATURE CITED

Aldrich, D.V., C.E. Wood and K.N. Baxter. 1968. An ecological interpretation of low temperature responses in *Penaeus aztecus* and *P. setiferus* postlarvae. Bull. Mar. Sci. 18(1):61-71.

Anderson, W.W. 1956. January to April distribution of the common shrimp on the South Atlantic Continental Shelf. U.S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish. 171. 14 p.

Anderson, W.W. 1966. The shrimp and the shrimp fishery of the southern United States. U.S. Fish. Wildl. Serv., Fish. Leafl. 589. 8 p.

Barrett, B.B. and M.C. Gillespie. 1973. Primary factors which influence commercial shrimp production in coastal Louisiana. La. Wildl. and Fish. Comm.

Baxter, K.N. 1969. Predicting shrimp abundance. Report of the Bureau of Commercial Fisheries, Biological Laboratory, Galveston, Texas, Fiscal Year, 1969. U.S. Fish and Wildlife Circular 343:13-14.

Baxter, K.N. and W.C. Renfro. 1966. Seasonal occurrence and size distribution of postlarval brown and white shrimp near Galveston, Texas, with notes on species identification. U.S. Fish Wildl. Serv., Fish Bull. 66:149-158.

Berry, R.B. and K.N. Baxter. 1967. Predicting brown shrimp abundance in the northwestern Gulf of Mexico. FAO World Scientific Converence on the Biology and Culture of Shrimps and Prowns, Experience paper, Mexico City. 25 p.

Bottino, N.R., J. Gennity, M.L. Lilly, E. Simmons and G. Finne. 1980. Seasonal and nutritional effects on the fatty acids of three species of shrimp, *Penaeus setiferus, P. aztecus* and *P. duorarum*. Aquaculture 19:139-148.

Broom, J.G. 1971. Shrimp culture. Proc. World Maricul. Soc. 1:53-72.

Brusher, H.A., W.C. Renfro and R.A. Neal. 1972. Notes on distribution, size, and ovarian development of some penaeid shrimps in the northwestern Gulf of Mexico, 1961-62. Cont. Mar. Sci. 16:75-87.

Caillouet, C.W., Fr. and K.N. Baxter. 1973. Gulf of Mexico shrimp resource research. Marine Fisheries Review 35(3-4):21-24.

Cook, H.L. 1966 . A generic key to the protozoean, mysis, and postlarval stages of the littoral Penaeidae of the Northwestern Gulf of Mexico. U.S. Fish and Wildl. Bull. 65(2):437-447.

Cook, H.L. and M.J. Lindner. 1970. Synopsis of biological data on the brown shrimp *Penaeus aztecus aztecus* Ives, 1891. FAO Fish. Rep. (57) Vol. 4, 1970.

Cook, H.L. and M.A. Murphy. 1969. The culture of larval penaeid shrimp. Trans. Amer. Fish. Soc. 1969 No. 4:751-754.

Cox, B.A. 1974. Responses of marine crustaceans *Mysidopsis almyra* Bowman, *Penaeus aztecus* Ives, and *Penaeus setiferus* (Linn.) to petroleum hydrocarbons. Dissertation, Biol. Dept., Texas A&M Univ., College Station, Tx. 167 p.

Dixon, W.J. and M.B.Brown (eds.). 1977. BMDP biomedical computer programs P-series 1977. Univ. Calif. Press.

Heegaard, P.E. 1953. Observations on spawning and larval history of the shrimp, *Penaeus setiferus* (L). Pub. Inst. Mar. Sci. 3(1)74-105.

Joyce, E.A. 1965. The commercial shrimps of the northeast coast of Florida. Fla. St. Bd. Conserv., Prof. Pap. Ser. 6. 224 p.

King, J.E. 1948. A study of the reproductive ograns of the common marine shrimp, *Penaeus setiferus* (Linnaeus). Biol. Bull. 94(3): 244-262.

Klima, E.F. 1964. Mark-recapture experiments with brown and white shrimp in the northern Gulf of Mexico. Proc. Gulf Caribbean Fish Inst. 10:52-64.

Klima, E.F. 1974. A white shrimp mark-recapture study. Trans. Am. Fish. Soc. 103(1):107-113.

Lawrence, A.L., D. Ward, S. Missler, A. Brown, J. McVey and B.S. Middleditch. 1979. Organ indices and biochemical levels of ova from penaeid shrimp maintained in captivity versus those captured in the wild. Proc. World Maricul. Soc. 10:453-463.

Lindner, M.J. and W.W. Anderson. 1956. Growth, migration, spawning, and size distribution of the shrimp, *Penaeus setiferus*. U.S. Fish Wildl. Serv., Fish. Bull. 56:555-645.

Lindner, M.J. and H.L. Cook. 1970. Synopsis of biological data on the white shrimp *Penaeus setiferus* (Linnaeus) 1967. FAO Fish. Rep. (57) Vol. 4:1432-1469.

Metzbower, H.T., S.S. Curry and S.A. Godshall. 1980. Handbook of the marine environment. Bryan Mound. NOAA report to DOE Strategic Petroleum Reserve Program, Salt Dome Storage/Brine. 92 p.

Middleditch, B.S., S.R. Missler, H.B. Hines, J.P. McVey, A. Brown, D.G. Ward and A.L. Lawrence. 1979. Metabolic profiles of penaeid shrimp:dietary lipids and ovarian maturation. Proc. Fourteenth Intern. Symp., Adv. in Chromatog, Lausanne, 24-28 Sept. 1979.

Middleditch, B.S., S.R. Missler, D.G. Ward, J. McVey, A. Brown and A.L. Lawrence. 1979. Maturation of penaeid shrimp:dietary fatty acids. Proc. World Maricul. Soc. 10:(in press).

Middleditch, B.S., S.R. Missler, H.B. Hines, E.S. Chang, J.P. McVey, A. Brown and A.L. Lawrence. 1980. Maturation of penaeid shrimp lipids in the marine food web. Proc. World. Mariculture Soc. 11: (in press).

Pequegnat, W.E. 1976. Ecological aspects of the upper continental slope of the Gulf of Mexico. Report prepared for the Bureau of Land Management for contract number 08550-CT4-12:305 p.

Perez Farfante, I. 1969. Western Atlantic shrimps of the genus *Penaeus*. Fish. Bull. 67(3):1-500.

Pullen, E.J. and N.L. Trent. 1969. White shrimp emigration in relation to size, sex, temperature and salinity. FAO Fish. Rep. 3(57):1001-1014.

Quarberg, D.M. 1974. Report on the culture of brown shrimp, *Penaeus aztecus* in ponds receiving thermal effluent from a power plant. Thesis, Dept. Wildl. Fish. Sci., Texas A&M Univ., College Station, TX. 225 p.

Renfro, W.C. and H.A. Brusher. 1963. Spawning populations. p. 13-17. In: Biological Laboratory, Galveston, Texas, Fishery research for the year ending June 30, 1962. U.S. Fish. Wildl. Serv., Circ. 161.

Rickards, W.L. and A.B. Williams. 1973. Shrimp culture feasibility study. p. 161-168. In: E.J. Kuenzler, A.F. Chestnut and C.M. Weiss (Eds.). Structure and functioning of estuarine ecosystems exposed to treated sewage wastes, III, 1971-1972. Univ. N. Car., Sea Grant Pub. UNC-SG-73-10. 222 p.

St. Amant, L.S., J.G. Broom and T.B. Ford. 1965. Studies of the brown shrimp, *Penaeus aztecus*, in Barataria Bay, Louisiana, 1962-1965. Proc. Gulf and Caribbean Fish Inst. 18:1017.

Subrahmanyam, C.B., 1976. Tidal and diurnal rhythms of locomotory activity and oxygen consumption in the pink shrimp, *Penaeus duorarum*. Cont. Mar. Sci. 20:23-132.

Sweet, W.E. 1974. Surface current study, northwestern Gulf of Mexico. Report: Study of naturally occurring hydrocarbons in the Gulf of Mexico. Texas A&M University, Oceanography Department.

Temple, R.K. and C.C. Fischer. 1965. Vertical distribution of the planktonic stages of penaeid shrimp. Pub. Inst. Mar. Sci., Univ. Tx. 10:59-67.

Temple, R.K. and C.C. Fischer. 1967. Seasonal distribution and relative abundance of planktonic-stage shrimp (*Penaeus* spp.) in the Northwestern Gulf of Mexico, 1961. Fish. Bull. 66(2)323-334.

United States Department of Energy. 1978. Final Environmental Impact Statement, Seaway Group Salt Domes. Volume 1 of 3. U.S. Department of Energy, Washington, D.C.

Williams, A.B. 1958. Substrates as a factor in shrimp distribution. Limnology and Oceanography 3(3):283-290.

Williams, A.B. 1959. Spotted and brown shrimp postlarvae (*Penaeus*) in North Carolina. Bull. Mar. Sci. 9(3):281-290.

Zein-Eldin, Z.P. and E.F. Klima. 1965. Effects of injected biological stains on oxygen uptake by shrimp. Trans. Amer. Fish. Soc. 94(3): 277-278.

APPENDIX: TABLES

Table 1. Samples planned and obtained as part of Work Unit 5.

YEAR:	1979	1980	1980	1980			1980		
SEASON:	Fall	Winter	Spring	Summer			Fall	Totals	
MONTH:	Oct-Nov	Feb	May	Jun	Jul	Aug	Sep	Planned	Obtained
Sample Types									
A. Search and Survey (27 stations)									
1. Trawl tows	81	81	81	81	81	81	81	567	567+
2. Bottom grabs for biochemical analyses		31		31				62	62
3. Bottom grabs for physical analyses	31			31				62	62+
4. Benthic sled for epifauna biochemical analyses		27		27				54	54
5. Hydrographic profiles	27	27	27	27	27	27	27	189	189
B. Intensive (9 stations)									
1. Trawl tows	27	27	27	27	27	27	27	189	189
2. Bottom grabs for eggs in sediments	27	27	-Discontinued by Contract Modification-					54	54
3. Benthic sled for overwintering postlarvae		27						27	27
4. Bottom sampling for eggs, larvae and postlarvae using Gulf V sampler (added by contract modification)			27	27	27	27	27	135	135
5. Bongo net tows	27	27	27	27	27	27	27	189	189
6. Hydrographic profiles	9	9	9	9	9	9	9	63	63
TOTALS	229	283	198	287	198	198	198	1,591	1,591

Table 2. Bottom temperatures (°C) and mean water depths recorded at all subblocks for cruises 1-7.

Cruise/ Date	BLOCK A Subblock								
	A1	A2	A3	A4	A5	A6	A7	A8	A9
Cruise 1 Oct-Nov 79	24.7	24.2	24.4	24.0	24.2	24.3	24.4	25.1	24.0
Cruise 2 Feb 80	16.5	15.7	15.7	15.7	17.4	17.6	18.2	18.5	17.6
Cruise 3 May 80	20.1	20.0	21.0	20.0	20.0	20.0	19.8	20.0	21.0
Cruise 4 June 80	20.0	20.1	20.3	20.2	20.7	20.1	20.1	19.9	20.0
Cruise 5 July 80	22.5	22.0	22.3	21.7	22.2	21.9	21.7	21.8	21.7
Cruise 6 Aug 80	25.6	27.3	27.7	26.4	25.3	23.8	23.4	23.4	23.3
Cruise 7 Sept 80	27.2	26.4	27.6	26.3	26.2	25.5	23.3	25.3	25.7
Mean Depth (m)	35	36	37	39	39	41	44	43	42

Cruise/ Date	BLOCK B Subblock								
	B1	B2	B3	B4	B5	B6	B7	B8	B9
Cruise 1 Oct-Nov 79	21.3	20.9	21.0	21.5	21.9	21.4	21.8	21.6	21.6
Cruise 2 Feb 80	13.0	13.0	13.5	13.6	13.8	13.2	14.8	14.5	14.3
Cruise 3 May 80	22.0	21.0	21.6	20.1	20.6	21.0	20.4	22.7	20.9
Cruise 4 June 80	27.7	27.6	26.6	25.5	25.9	25.8	26.1	25.5	24.8
Cruise 5 July 80	28.6	28.6	28.5	25.0	26.1	26.6	24.5	24.1	24.4
Cruise 6 Aug 80	29.6	29.7	29.8	29.2	29.6	29.6	28.7	28.7	28.9
Cruise 7 Sept 80	30.2	20.1	29.7	29.9	30.1	29.8	28.2	27.9	27.5
Mean Depth (m)	11	14	10	17	19	18	22	22	21

Cruise/ Date	BLOCK C Subblock								
	C1	C2	C3	C4	C5	C6	C7	C8	C9
Cruise 1 Oct-Nov 79	24.2	23.5	24.3	24.0	24.0	24.2	24.4	24.3	24.2
Cruise 2 Feb 80	14.1	14.5	14.9	14.9	14.0	14.5	15.1	14.9	15.0
Cruise 3 May 80	22.7	22.6	22.2	21.1	21.3	21.3	20.9	21.0	20.8
Cruise 4 June 80	26.8	25.8	25.0	24.6	24.8	24.8	24.6	25.0	24.5
Cruise 5 July 80	29.5	28.9	29.1	27.1	26.6	25.5	24.0	24.4	24.0
Cruise 6 Aug 80	28.6	29.0	29.0	28.9	29.0	28.8	28.8	28.6	29.0
Cruise 7 Sept 80	26.9	27.0	27.7	27.4	26.9	27.2	28.0	26.9	27.3
Mean Depth (m)	12	15	15	19	20	22	23	23	22

Table 3a. Bottom conductivity values (μmhos/100 cm) and mean depth at all subblocks for cruises 1-7. See Table 3b for conversion of conductivity to salinity nomograph.

Cruise/ Date	BLOCK A Subblock								
	A1	A2	A3	A4	A5	A6	A7	A8	A9
Cruise 1 Oct-Nov 79	469	487	483	500	488	490	493	503	300
Cruise 2 Feb 80	547	542	543	543	551	548	557	559	553
Cruise 3 May 80	536	545	538	550	525	532	522	526	527
Cruise 4 June 80	520	517	518	517	522	530	531	522	530
Cruise 5 July 80	540	542	540	544	541	540	540	540	541
Cruise 6 Aug 80	536	536	531	540	535	539	540	541	540
Cruise 7 Sept 80	514	508	520	525	522	499	520	526	522
Mean Depth (m)	35	36	37	39	39	41	44	43	42

Cruise/ Date	BLOCK B Subblock								
	B1	B2	B3	B4	B5	B6	B7	B8	B9
Cruise 1 Oct-Nov 79	408	411	410	453	456	428	468	468	471
Cruise 2 Feb 80	451	453	487	483	487	481	516	498	498
Cruise 3 May 80	500	528	514	545	545	435	545	539	530
Cruise 4 June 80	338	350	413	455	449	448	450	458	480
Cruise 5 July 80	524	521	515	527	526	529	528	533	530
Cruise 6 Aug 80	485	485	481	502	488	490	530	527	528
Cruise 7 Sept 80	497	497	489	486	491	497	470	479	465
Mean Depth (m)	11	14	10	17	19	18	22	22	21

Cruise/ Date	BLOCK C Subblock								
	C1	C2	C3	C4	C5	C6	C7	C8	C9
Cruise 1 Oct-Nov 79	472	471	491	488	493	489	488	491	492
Cruise 2 Feb 80	485	508	505	515	500	506	524	525	524
Cruise 3 May 80	513	501	514	513	530	522	528	540	541
Cruise 4 June 80	432	468	468	481	477	469	493	491	484
Cruise 5 July 80	529	534	534	531	533	533	526	537	536
Cruise 6 Aug 80	515	513	513	515	518	527	516	534	512
Cruise 7 Sept 80	485	489	495	467	465	487	455	468	470
Mean Depth (m)	12	15	15	19	20	22	23	23	22

Table 3b. Conductivity and respective salinity values. Conductivity values in Table 3a are referenced to 25 C. A value of 500 from Table 3a is equivalent to 50 on the above scale and is equal to about 33 ppt salinity.

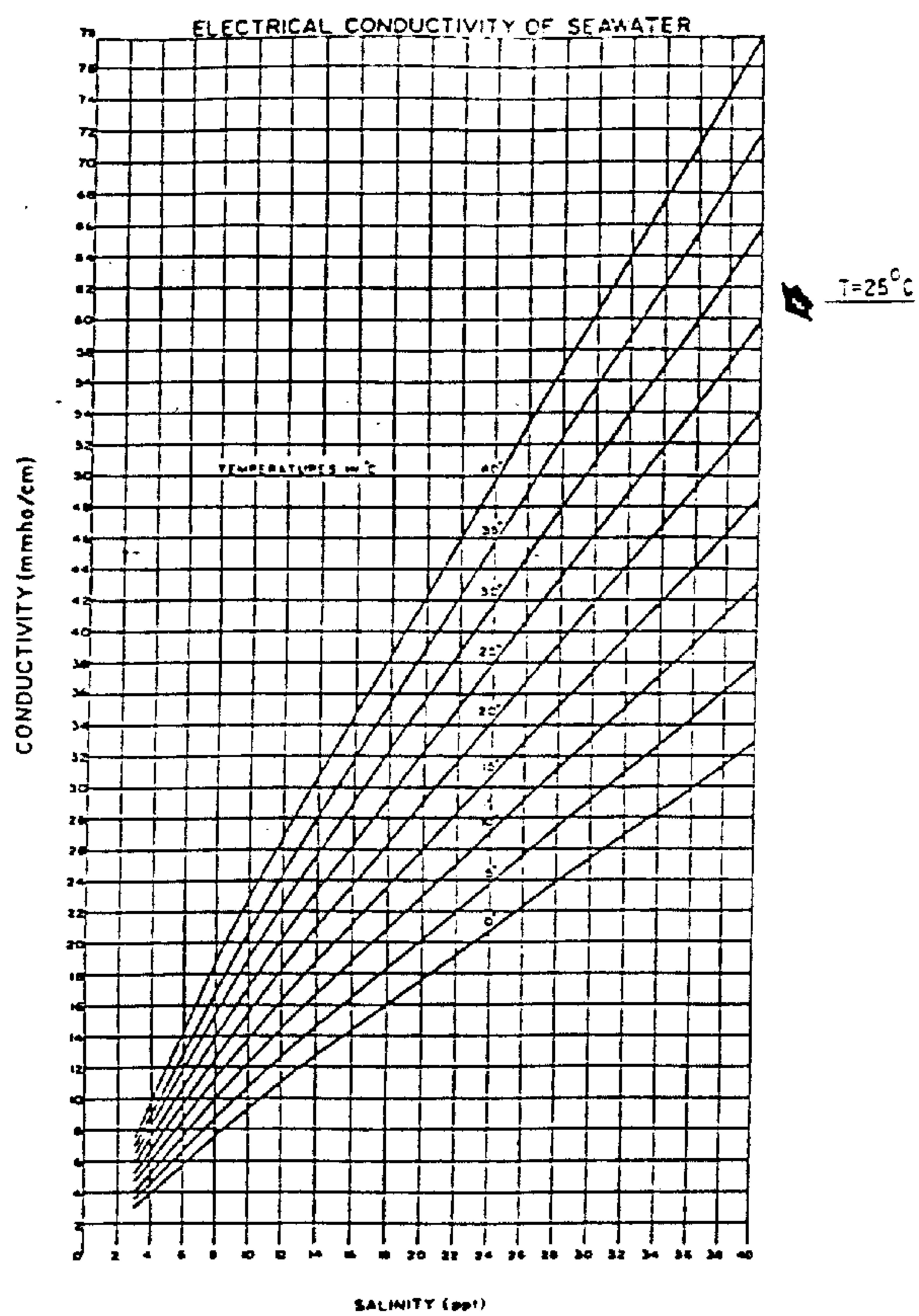

Table 4. Dissolved oxygen (mg/l) and mean water depths (m) recorded at all subblocks for cruises 1-7.

Cruise/ Date	BLOCK A Subblock									BLOCK B Subblock									BLOCK C Subblock								
	A1	A2	A3	A4	A5	A6	A7	A8	A9	B1	B2	B3	B4	B5	B6	B7	B8	B9	C1	C2	C3	C4	C5	C6	C7	C8	C9
Cruise 1 Oct-Nov 79	7.5	7.5	7.6	7.6	7.6	7.5	5.9	7.5	7.6	7.3	7.1	6.1	7.7	7.5	7.4	8.1	8.1	8.0	8.0	7.8	7.6	7.3	7.4	7.7	6.9	7.3	6.4
Cruise 2 Feb 80	9.2	9.3	9.3	9.1	8.8	9.0	8.9	8.9	9.1	10.2	10.6	8.3	10.1	10.1	9.7	10.0	10.2	10.1	8.1	8.7	9.0	9.3	8.9	9.2	9.6	9.4	9.6
Cruise 3 May 80	7.4	7.3	8.4	7.4	7.2	6.9	9.1	7.1	8.5	7.9	7.0	7.1	8.4	9.8	8.3	8.2	8.5	9.3	7.5	7.1	7.0	6.9	7.0	6.7	6.9	7.7	8.9
Cruise 4 June 80	6.6	7.2	7.1	7.5	6.5	6.6	6.0	8.8	6.0	7.7	7.5	4.0	5.4	4.2	4.4	6.3	4.8	4.2	2.9	3.9	2.5	3.0	3.0	2.4	7.6	7.3	6.2
Cruise 5 July 80	8.2	8.0	8.1	8.1	8.4	8.0	8.2	8.2	8.2	6.4	6.1	5.6	6.7	6.3	5.7	7.1	7.2	7.0	5.4	6.1	6.4	7.4	6.6	6.2	7.4	7.1	6.9
Cruise 6 Aug 80	5.5	6.0	6.3	6.1	5.8	6.4	7.0	7.0	7.0	6.7	6.1	6.3	6.0	6.6	6.4	6.5	6.6	6.3	6.7	7.0	7.2	6.8	7.3	6.7	7.2	6.6	7.0
Cruise 7 Sept 80	4.8	4.0	4.4	5.3	4.4	3.4	3.1	4.5	4.2	6.9	6.9	6.9	6.4	6.6	6.0	6.3	5.2	5.0	5.7	5.5	6.0	5.2	5.6	5.3	4.5	5.1	5.0
Mean Depth (m)	35	36	37	39	39	41	44	43	42	11	14	10	17	19	18	22	22	21	12	15	15	19	20	22	23	23	22

Table 5. Fatty acid concentrations (ppm) in sediment samples collected from blocks A, B and C, February 1980. Levels of 0 indicate value was below 0.1 ppm.

	Fatty Acid																				
Station	14:0	14:1	15:0	15:1	16:0	16:1	17:0	17:1	18:0	18:1	18:2	18:3	20:0	20:1	20:4	20:5	21:0	22:3	22:4	22:5	22:6	Total
A1	0.6	0.5	0.2	0.2	2.3	1.5	0.2	0.1	0.6	1.1	0.2	1.0	0.0	0.0	0.4	0.3	0.2	0.2	0.2	0.0	0.0	9.6
A2	0.7	1.0	0.3	0.3	4.1	2.1	0.4	0.2	1.2	3.4	0.5	1.2	0.0	0.0	0.2	0.0	0.0	0.3	0.4	0.2	0.0	16.5
A3	0.7	0.9	0.4	0.3	3.2	1.9	0.4	0.1	0.8	1.5	0.2	0.2	0.0	0.2	0.0	0.0	0.0	0.1	0.2	0.1	0.0	11.2
A4	0.0	0.0	0.0	0.0	69.8	6.2	0.0	0.0	31.5	14.4	37.0	43.1	6.2	0.0	0.0	86.3	0.0	18.5	0.0	0.0	0.0	313.0
A5	0.4	0.5	0.2	0.1	1.9	1.1	0.2	0.0	0.5	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
A6	0.3	0.2	0.1	0.1	0.8	0.4	0.1	0.0	0.5	0.8	0.4	0.4	0.0	0.0	0.1	0.0	0.1	0.2	0.0	0.2	0.0	4.7
A7	0.4	0.4	0.2	0.2	2.1	0.8	0.3	0.0	0.9	4.5	0.3	3.6	0.3	0.0	0.0	0.0	0.4	0.7	0.4	0.0	0.0	15.5
A8	0.6	0.7	0.2	0.2	2.0	1.1	0.3	0.1	0.7	1.2	0.3	4.7	0.5	0.0	0.0	0.0	0.0	0.4	0.3	0.2	0.0	13.5
A9	0.6	0.8	0.3	0.3	3.2	2.0	0.3	0.1	0.8	1.5	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	10.9
MEAN	0.5	0.6	0.2	0.2	9.9	1.9	0.2	0.1	4.2	3.3	4.4	6.1	0.8	0.02	0.1	9.6	0.1	2.3	0.2	0.1	0.0	44.5
B1	0.3	0.2	0.1	0.1	1.9	0.7	0.2	0.1	1.2	1.1	0.3	1.6	0.1	0.3	0.0	0.1	0.2	0.1	0.1	0.1	0.0	8.8
B2	1.3	0.9	0.5	0.5	6.5	2.7	0.8	0.0	2.7	2.5	1.3	4.3	0.3	0.0	0.5	0.9	0.9	0.6	1.7	0.5	0.3	29.7
B3	5.9	3.1	3.8	1.1	17.9	13.0	2.1	1.9	5.3	6.6	1.1	4.3	0.3	0.0	2.4	5.6	0.6	1.0	2.3	0.6	2.5	81.4
B4	5.9	3.7	4.0	1.2	16.3	9.5	1.8	1.4	2.9	4.7	0.6	0.5	0.0	0.6	0.6	1.1	0.1	0.1	1.3	0.3	0.4	57.0
B5	0.0	0.0	0.0	0.0	24.8	11.3	18.0	0.0	34.4	31.6	27.0	36.0	0.0	0.0	0.0	6.8	0.0	45.1	0.0	0.0	0.0	235.0
B6	1.3	0.7	0.4	0.4	2.9	0.8	0.6	0.1	1.7	1.4	0.7	9.1	0.9	0.0	0.0	0.0	0.0	1.0	1.0	0.5	0.0	23.5
B7	0.0	0.0	0.0	0.0	440.8	52.6	59.2	0.0	120.4	111.9	98.7	401.4	52.6	0.0	0.0	177.6	0.0	59.2	0.0	65.8	0.0	1640.2
B8	0.0	0.0	0.0	0.0	87.9	26.4	149.4	0.0	34.1	408.7	33.0	118.7	3.3	0.0	0.0	61.5	0.0	35.2	0.0	13.2	0.0	971.4
B9	1.3	1.3	0.9	0.4	5.0	3.4	0.6	0.4	1.0	2.4	0.4	0.5	0.0	0.2	0.5	0.7	0.1	0.2	0.5	0.2	0.2	20.2
MEAN	1.8	1.1	1.1	0.4	67.1	13.4	25.9	0.4	22.6	63.4	18.1	64.0	6.4	0.1	0.4	28.3	0.2	15.8	0.8	9.0	0.4	340.8
*C1	1.6	1.3	0.8	0.4	5.2	3.3	0.9	0.4	1.4	2.4	0.4	0.7	0.0	0.3	0.4	0.7	0.1	0.2	0.6	0.2	0.4	21.7
C2	3.2	2.3	1.7	1.1	11.0	7.2	2.1	0.7	4.2	224.1	2.2	1.2	1.4	0.7	1.8	3.8	1.0	15.1	2.3	0.6	2.1	289.8
C3	2.7	2.3	1.3	1.1	9.7	6.8	2.0	0.0	3.8	221.8	2.0	2.0	0.8	0.4	1.6	1.9	0.9	13.3	2.1	0.4	0.9	277.8
C4	3.3	2.3	1.7	0.7	9.5	5.9	0.9	0.8	2.0	3.6	0.5	0.4	0.0	0.4	0.6	1.0	0.0	0.2	0.9	0.4	0.0	35.1
C5	1.8	2.1	1.0	0.6	6.1	4.1	1.1	1.3	1.9	4.0	1.1	6.5	0.6	0.0	0.7	0.5	0.8	1.0	1.3	0.3	0.2	37.0
*C6	4.9	3.0	2.5	1.0	12.7	7.2	1.5	1.1	3.2	4.7	1.0	2.0	0.0	0.0	0.5	3.0	0.3	0.4	1.5	0.3	0.0	50.8
C7	0.0	0.0	0.0	0.0	77.2	11.2	39.3	0.0	18.2	12.6	12.6	64.6	2.8	0.0	0.0	36.5	0.0	14.0	0.0	0.0	0.0	289.0
C8	0.0	0.0	0.0	0.0	15.6	6.9	12.1	0.0	26.3	131.9	17.4	22.6	0.0	0.0	0.0	10.4	0.0	27.8	0.0	0.0	0.0	271.0
C9	0.0	0.0	0.0	0.0	67.7	25.4	54.2	0.0	21.0	64.3	0.0	101.6	0.0	0.0	0.0	15.2	0.0	30.5	0.0	0.0	0.0	379.9
MEAN	1.9	1.5	1.0	0.5	23.9	8.7	12.7	0.5	9.1	74.4	4.1	22.4	0.6	0.2	0.6	8.1	0.3	11.4	1.0	0.2	0.4	183.6

Table 6. Fatty acid concentrations (ppm) in sediment samples collected from blocks A, B and C, June 1980. Levels of 0 indicate value was below 0.1 ppm.

Station	Fatty Acid 14:0	14:1	15:0	15:1	16:0	16:1	17:0	17:1	18:0	18:1	18:2	18:3	20:0	20:1	20:4	20:5	21:0	22:3	22:4	22:5	22:6	Total
A1	0.3	0.4	0.2	0.1	1.5	0.7	0.1	0.0	0.5	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7
A2	1.2	1.0	0.5	0.3	5.1	2.6	0.4	0.1	1.0	1.6	0.2	0.4	0.0	0.2	0.2	0.3	0.0	0.0	0.1	0.2	0.2	15.6
A3	0.4	0.4	0.3	0.1	2.5	0.9	0.2	0.0	0.9	1.1	0.4	0.0	0.0	0.0	0.2	0.7	0.0	0.1	0.3	0.3	0.0	8.8
A4	0.4	0.1	0.2	0.0	2.0	0.3	0.2	0.1	1.2	0.9	0.7	0.3	0.0	0.0	0.0	0.6	0.0	0.1	0.2	0.5	0.2	8.0
A5	0.4	0.4	0.2	0.1	2.0	0.8	0.1	0.0	0.6	1.0	0.3	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.1	0.0	0.0	6.4
A6	0.2	0.2	0.1	0.0	1.2	0.4	0.1	0.0	0.6	0.7	0.2	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.1	0.1	4.3
A7	0.4	0.5	0.2	0.2	1.8	0.6	0.2	0.0	0.8	0.9	0.3	0.0	0.0	0.0	0.1	0.3	0.0	0.1	0.0	0.2	0.1	6.7
A8	0.3	0.5	0.2	0.1	1.7	0.8	0.2	0.0	0.5	0.9	0.2	0.1	0.0	0.1	0.0	0.4	0.0	0.1	0.1	0.2	0.0	6.4
A9	0.4	0.3	0.2	0.2	1.9	0.7	0.2	0.1	0.8	1.1	0.4	0.2	0.1	0.1	0.0	0.2	0.1	0.5	0.2	0.1	0.2	8.0
MEAN	0.4	0.4	0.2	0.1	2.2	0.9	0.2	0.0	0.8	1.0	0.3	0.1	0.0	0.0	0.1	0.4	0.0	0.1	0.1	0.2	0.1	7.7
B1	3.4	2.0	1.7	0.5	14.2	6.8	1.1	0.5	5.1	5.3	2.1	0.0	0.0	0.0	0.0	1.3	0.0	0.2	1.1	0.8	1.2	47.3
B2	3.0	0.8	0.8	0.5	10.4	2.2	0.7	0.3	6.3	5.1	3.1	1.1	0.0	0.0	1.0	3.1	0.0	0.5	0.9	1.8	2.4	44.0
B3	1.6	1.2	0.7	0.3	5.5	3.3	0.4	0.1	1.2	1.7	0.2	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.1	0.1	0.1	31.2
B4	0.2	0.1	0.1	0.0	0.8	0.3	0.1	0.0	0.3	0.5	0.2	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	2.9
B5	1.6	1.3	0.8	0.4	5.5	2.4	0.6	0.3	1.5	2.1	0.7	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	17.5
B6	3.6	0.0	2.4	0.5	16.3	2.1	1.6	0.0	11.8	8.7	7.8	2.3	0.0	0.0	7.6	22.3	0.0	0.9	2.3	6.0	0.0	96.2
B7	1.8	1.3	1.9	0.4	7.5	3.1	0.8	0.6	2.1	2.5	0.8	0.0	0.0	0.0	0.0	1.1	0.0	0.1	0.3	0.4	0.0	24.7
B8	0.6	0.4	0.4	0.1	2.4	0.7	0.3	0.1	1.1	0.9	0.4	0.2	0.0	0.0	0.0	0.5	0.0	0.0	0.2	0.3	0.0	8.6
B9	0.9	1.0	0.5	0.3	3.2	1.5	0.3	0.2	1.0	1.4	0.4	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.2	0.1	0.2	11.6
MEAN	1.9	0.9	1.0	0.3	7.3	2.5	0.7	0.2	3.4	3.1	1.7	0.4	0.0	0.0	1.0	3.2	0.0	0.2	0.6	1.1	0.4	31.6
*C1	1.1	0.4	1.0	0.1	3.9	1.6	0.3	0.3	0.8	0.9	0.2	0.2	0.0	0.2	0.2	0.3	0.0	0.0	0.1	0.2	0.1	11.9
C2	5.3	1.8	2.2	0.8	18.9	4.7	1.3	0.4	5.6	5.1	1.5	1.4	0.0	1.5	0.8	3.7	0.2	0.3	0.9	1.4	1.1	58.9
C3	3.4	2.2	1.2	0.7	9.2	6.0	0.9	0.5	2.1	3.2	0.7	0.3	0.0	0.3	0.3	0.7	0.1	0.1	0.9	0.4	0.3	33.5
C4	1.2	0.9	0.6	0.2	3.9	1.4	0.4	0.0	1.4	1.4	0.6	0.4	0.0	0.4	0.0	0.7	0.0	0.1	0.4	0.4	0.1	14.5
C5	1.3	1.2	0.7	0.4	4.4	1.8	0.5	0.2	1.5	1.7	0.5	0.2	0.0	0.0	0.0	0.9	0.0	0.1	0.2	0.4	0.1	16.1
*C6	6.0	1.9	4.7	0.7	22.7	9.5	1.8	1.0	5.7	4.5	2.5	0.9	0.0	0.6	0.0	2.7	0.0	0.6	1.0	1.9	0.0	68.7
C7	1.2	1.1	0.7	0.3	3.7	2.0	0.3	0.1	0.9	1.4	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.2	0.2	0.0	12.8
C8	1.0	0.9	0.5	0.2	2.9	1.9	0.3	0.1	0.9	1.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.2
C9	0.5	0.3	0.3	0.0	1.9	0.6	0.2	0.0	0.8	0.8	0.4	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.3	0.2	6.9
MEAN	2.3	1.2	1.3	0.4	8.0	3.3	0.7	0.3	2.2	2.2	0.8	0.4	0.0	0.3	0.1	1.1	0.0	0.1	0.4	0.6	0.2	25.9

Table 7. Fatty acid concentrations (ppm) in biota samples collected from blocks A, B and C, February 1980. Levels of 0 indicate value was below 0.1 ppm.

Station	Fatty Acids																								Total
	14:0	14:1	15:0	15:1	16:0	16:1	17:0	17:1	18:0	18:1	18:2	18:3	20:0	20:1	20:4	20:5	21:0	22:3	22:4	22:5	22:6				
A1	5166	221	1329	148	24579	8192	2509	664	9762	9521	590	2435	148	1107	0	517	183	183	137	183	1374				68,948
A2	196	36	202	59	2257	653	327	77	979	1307	119	0	12	154	1223	1176	131	83	71	71	1105				10,238
A3	81	5	126	25	1722	419	283	96	747	1005	91	0	5	131	899	990	106	86	50	61	1071				7,999
A4	354	16	166	43	2051	977	295	102	865	1031	107	0	11	220	854	1696	129	86	113	81	1465				10,662
A5	462	32	227	57	3336	1441	373	105	1286	1652	162	0	16	292	1401	2381	130	130	138	227	2187				16,035
A6	360	16	144	32	2081	752	304	72	976	832	144	0	8	376	128	432	88	40	16	16	56				6,873
A7	794	76	302	38	6350	2117	794	151	2560	3175	454	0	76	113	1550	2268	151	151	189	113	1663				23,085
A8	329	59	204	72	2799	1739	382	151	1023	1495	171	303	33	382	1218	2226	184	316	204	329	2088				15,707
A9	508	20	156	20	3441	1294	325	88	1170	1734	217	0	54	318	610	2818	102	135	142	196	2425				15,773
MEAN	917	53	317	55	5402	1954	621	167	2152	2417	228	304	40	344	876	1612	134	134	118	142	1493				19,480
B1	428	60	223	60	3030	1010	411	154	1434	1703	171	0	51	334	599	2260	188	103	111	180	1849				14,359
B2	386	64	209	64	3047	1109	418	161	1330	1672	177	0	32	322	804	2862	201	113	137	217	2428				15,753
B3	454	122	203	81	3323	1216	421	146	1371	1475	170	866	130	348	835	3015	308	146	146	194	2545				17,515
B4	558	72	189	54	3635	1440	450	171	1506	1584	180	0	27	270	540	1692	153	72	81	117	1188				13,979
B5	276	40	121	40	2451	754	323	108	1108	1145	135	0	20	202	687	2195	135	67	88	121	1831				11,847
B6	488	49	195	59	3941	1317	488	127	1638	1658	176	0	20	351	1044	3414	215	146	185	302	2946				18,759
B7	811	55	159	43	3246	1501	305	122	1012	1373	183	0	49	232	647	2270	116	110	122	110	1843				14,309
B8	691	75	191	58	4027	1664	408	125	1414	1789	208	333	67	300	998	2504	200	108	166	141	2155				17,622
B9	310	51	152	51	2362	861	367	146	1074	1494	177	253	25	253	905	2526	152	152	101	177	1900				13,489
MEAN	489	65	182	57	3229	1208	358	140	1321	1544	175	161	47	290	784	2526	185	113	126	173	2076				15,292
*C1	178	23	155	47	2698	682	341	78	1288	1225	171	0	39	271	667	1907	217	109	101	124	1977				12,298
C2	812	122	300	78	4403	1823	534	200	1867	3814	334	0	100	445	1090	4092	322	256	233	222	4047				25,094
C3	203	35	154	49	2454	715	323	98	1152	1262	168	0	35	252	729	1942	196	98	91	84	2005				12,045
C4	556	121	323	101	4222	1717	545	212	1770	2424	323	0	101	606	1091	3697	333	192	202	273	3738				22,547
C5	305	30	175	53	3225	899	343	84	1285	1394	213	290	91	320	823	2513	259	122	129	129	2635				15,317
*C6	1946	150	299	64	6523	3444	460	257	1806	2887	460	0	235	492	920	4427	160	171	225	171	3476				28,573
C7	564	40	201	50	4362	1511	423	91	1630	1894	272	0	60	282	1249	3324	201	101	161	161	3032				19,609
C8	1517	95	322	57	4247	2853	512	237	1729	2957	360	721	95	588	967	5801	246	360	284	559	4019				28,526
C9	357	25	170	51	3519	1054	340	85	1422	1513	195	0	42	263	1020	2414	153	76	102	127	2278				15,206
MEAN	715	71	233	61	3961	1633	424	149	1550	2152	277	112	89	391	951	3346	232	165	170	206	3023				19,913

Table 8. Fatty acid concentrations (ppm) in biota samples collected from blocks A, B and C, June 1980. Levels of 0 indicate value was below 0.1 ppm.

	Fatty Acids																					
Station	14:0	14:1	15:0	15:1	16:0	16:1	17:0	17:1	18:0	18:1	18:2	18:3	20:0	20:1	20:4	20:5	21:0	22:3	22:4	22:5	22:6	Total
A1	88	0	96	15	2268	707	265	236	1246	2496	191	0	0	280	368	368	103	0	22	0	162	8,911
A2	279	10	155	21	3579	2011	392	165'	1846	2847	206	0	0	351	1021	3198	155	165	72	165	1248	17,886
A3	716	99	368	109	5331	3252	706	358	1604	2477	229	0	20	875	1114	2317	278	259	179	189	1223	21,703
A4	43	0	60	26	1398	571	222	102	1321	2046	315	0	17	205	827	1467	119	111	43	281	486	9,660
A5	289	36	265	60	4534	2002	555	241	2185	3232	301	0	36	422	2002	4752	241	277	217	350	2870	24,867
A6	232	12	110	24	5015	2495	440	269	1821	4941	294	0	0	367	1602	3669	171	330	171	196	1712	23,871
A7	441	28	197	28	3414	1576	431	169	1613	2392	263	0	0	356	769	1914	169	131	113	188	1135	15,327
A8	297	35	315	70	3984	1555	568	227	1414	1477	218	0	52	839	1180	2342	315	315	210	227	1809	17,449
A9	331	0	286	45	5459	1985	767	406	2758	5023	541	0	60	692	3218	7670	451	602	451	737	4918	36,400
MEAN	302	24	206	44	3887	1795	483	241	1756	2992	284	0	21	487	1345	3077	222	243	164	259	1729	19,564
B1	496	186	434	186	6699	2791	1116	837	5703	6854	1706	0	217	1489	4590	9769	744	744	0	1427	4962	50,950
B2	408	0	286	41	5078	1815	612	122	3246	2611	326	0	41	632	1427	3345	326	265	163	367	1999	23,100
B3	414	0	0	0	7313	1242	1242	828	5224	3449	3863	0	276	276	414	1932	1104	828	1518	0	2898	32,820
B4	1160	60	266	36	4932	3119	423	302	1793	2587	242	0	24	169	798	1861	85	145	109	97	846	19,054
B5	223	0	171	26	3888	1603	552	236	2294	2995	302	0	0	552	1103	2443	289	158	118	236	1261	18,450
B6	503	0	243	35	5399	2205	590	278	2847	2812	365	0	17	486	1805	3090	260	156	139	208	1701	23,139
B7	617	0	357	49	5389	1753	617	179	2532	2727	260	0	0	390	1331	2045	277	195	179	276	1591	20,714
B8	622	33	344	65	5517	2046	688	311	2820	3110	409	0	0	507	2619	4747	327	458	360	507	2947	28,437
B9	1750	75	525	75	8150	3325	1000	650	4375	4675	500	0	0	1000	2125	6000	325	425	225	450	2500	38,150
MEAN	688	39	292	57	5818	2211	760	416	3426	3536	886	0	64	611	1801	3915	410	375	312	396	2301	28,314
*C1	528	0	333	56	6501	2139	833	445	4306	3139	278	0	0	833	83	389	222	0	0	0	0	20,085
C2	0	0	0	0	5810	17429	0	2905	13885	5810	0	0	1452	17429	58096	7262	0	11619	15977	45025	0	202,699
C3	210	0	160	25	3407	1382	494	222	2135	2666	309	0	49	407	2222	4135	309	370	284	407	2419	21,612
C4	556	35	296	70	5739	2365	713	278	2853	3408	487	0	70	417	3408	4973	348	400	278	417	3443	30,554
C5	599	29	263	44	4707	1959	585	278	2566	2690	365	0	58	409	2339	4400	263	322	190	322	2909	25,297
*C6	632	16	221	32	4551	2433	632	442	2605	3350	442	0	32	569	2339	4456	348	569	316	506	2117	26,608
C7	799	0	342	0	8105	3596	1027	514	4458	5593	571	0	0	571	2226	3253	285	228	0	342	1712	42,622
C8	396	0	169	17	3146	941	409	99	1741	1479	167	0	0	196	666	1286	104	73	69	136	892	11,986
C9	507	8	155	16	2610	1178	327	90	1182	1276	139	0	8	82	892	1407	82	65	131	90	990	11,235
MEAN	470	10	215	29	4953	3714	558	586	3970	3268	306	0	185	2324	8030	3507	218	1516	1916	5249	1609	43,633

Table 9. Sterol concentrations (ppm) in sediment samples collected from blocks A, B and C, February 1980. Levels of 0 indicate value was below 0.1 ppm.

	Sterols							
Station	22-trans-24 Narcholesta 5, 22 dien, 3β-01	22-Dehydro-Cholesterol	Cholesterol	Brassica-Sterol	24-Methyl-Cholesterol	Stigma-Sterol	Sito-sterol	Total
A1	0.3	1.4	5.1	2.4	1.0	1.6	2.2	14.0
A2	0.0	1.8	4.2	3.8	2.6	3.6	3.7	19.7
A3	0.0	1.5	4.5	2.8	1.5	2.6	3.1	16.0
A4	0.0	1.2	3.6	2.3	1.3	2.4	2.4	13.2
A5	0.2	0.8	2.8	1.9	0.9	1.6	1.9	10.1
A6	0.0	0.5	1.9	0.8	0.4	0.6	0.1	4.3
A7	0.0	0.6	1.7	1.2	0.5	1.1	1.5	6.6
A8	0.0	1.0	2.7	1.8	0.8	1.5	2.0	9.8
A9	0.0	1.4	3.2	3.1	1.9	2.6	2.1	14.3
MEAN	0.1	1.1	3.3	2.2	1.2	2.0	2.1	12.0
B1	0.5	1.9	19.5	2.8	2.4	0.6	1.4	29.1
B2	2.0	3.1	13.9	5.4	7.1	4.6	8.8	44.9
B3	1.4	6.0	16.9	13.1	12.4	7.9	12.7	70.4
B4	1.8	5.9	15.8	12.3	10.4	9.2	10.3	65.7
B5	2.4	5.8	10.7	9.3	7.5	7.8	11.5	55.0
B6	0.6	0.7	2.7	1.2	1.0	0.9	1.7	8.8
B7	0.6	1.6	4.3	2.5	1.9	2.4	3.2	16.5
B8	0.8	2.5	7.8	5.0	3.8	4.5	6.0	30.4
B9	0.6	2.4	6.2	4.6	3.2	3.6	4.7	25.3
MEAN	1.2	3.3	10.9	6.2	5.5	4.6	6.7	38.5

.....cont'd

Table 9 cont'd

Station	Sterols							Total
	22-trans-24 Narcholesta 5, 22 dien, 3β-01	22-Dehydro-Cholesterol	Cholesterol	Brassica-Sterol	24-Methyl-Cholesterol	Stigma-Sterol	Sito-sterol	
C1	1.3	2.5	7.7	5.1	3.1	3.2	4.3	27.2
C2	3.5	5.3	14.6	12.5	7.4	6.5	9.8	59.6
C3	2.8	5.7	27.4	9.9	5.7	5.8	8.3	65.6
C4	1.9	4.2	10.6	8.6	5.4	5.9	8.3	44.9
C5	1.9	4.5	9.9	7.8	6.2	7.5	9.9	47.7
C6	1.4	3.4	10.3	6.4	5.1	6.2	8.0	40.8
C7	0.8	3.3	31.0	5.3	2.9	3.5	4.9	51.7
C8	0.4	1.7	5.1	3.4	2.0	2.6	3.5	18.7
C9	0.9	2.8	9.5	5.3	3.6	4.3	5.2	31.6
MEAN	1.7	3.7	14.0	7.1	4.6	5.1	6.9	43.1

Table 10. Sterol concentrations (ppm) in sediment samples collected from blocks A, B and C, June 1980. Levels of 0 indicate value was below 0.1 ppm.

	Sterols							
Station	22-trans-24 Norcholesta 5, 22-dien, 3β-01	22-Dehydro-Cholesterol	Cholesterol	Brassica-Sterol	24-Methyl-Cholesterol	Stigma-Sterol	Sito-Sterol	Total
A1	0.0	0.2	0.5	0.3	0.2	0.2	0.3	1.7
A2	0.2	0.8	2.0	1.3	0.5	0.6	0.8	6.2
A3	0.1	0.2	0.2	0.4	0.2	0.3	0.4	1.8
A4	0.1	0.1	0.2	0.3	0.2	0.2	0.3	1.4
A5	0.1	0.2	0.5	0.5	0.2	0.4	0.4	2.3
A6	0.0	0.1	0.3	0.3	0.2	0.2	0.2	1.3
A7	0.1	0.2	0.4	0.4	0.2	0.3	0.4	2.0
A8	0.1	0.2	0.4	0.4	0.2	0.4	0.5	2.2
A9	0.0	0.2	0.5	0.4	0.2	0.3	0.3	1.9
MEAN	0.1	0.2	0.6	0.5	0.2	0.3	0.4	2.3
B1	0.4	0.5	1.8	1.0	1.4	0.9	1.9	7.9
B2	0.2	0.3	1.3	0.5	0.6	0.4	0.8	4.1
B3	0.2	0.6	2.0	0.9	1.1	0.3	0.6	5.7
B4	0.0	0.1	0.2	0.1	0.1	0.1	0.1	0.7
B5	0.2	0.7	1.5	0.9	0.8	0.8	1.2	6.1
B6	0.2	0.2	0.3	0.4	0.3	0.2	0.5	2.1
B7	0.2	0.6	1.2	0.8	0.7	0.7	1.0	5.2
B8	0.1	0.2	0.3	0.3	0.3	0.3	0.4	1.9
B9	0.1	0.4	1.2	0.6	0.5	0.5	0.7	4.0
MEAN	0.2	0.4	1.1	0.6	0.6	0.5	0.8	4.2

.....cont'd

Table 10 cont'd

Station	Sterols							Total
	22-trans-24 Norcholesta 5, 22-dien, 3β-01	22-Dehydro-Cholesterol	Cholesterol	Brassica-Sterol	24-Methyl-Cholesterol	Stigma-Sterol	Sito-Sterol	
C1	0.1	0.2	1.2	0.4	0.5	0.2	0.4	3.0
C2	0.4	0.8	2.4	1.5	0.8	0.7	1.1	7.7
C3	0.4	1.0	2.4	1.6	1.3	1.1	1.7	9.5
C4	0.1	0.3	0.6	0.6	0.5	0.5	0.7	3.3
C5	0.2	0.5	0.8	0.8	0.7	0.8	1.1	4.9
C6	0.2	0.5	0.6	0.9	0.7	0.8	1.0	4.7
C7	0.1	0.3	0.5	0.5	0.4	0.4	0.6	2.8
C8	0.1	0.3	0.5	0.5	0.4	0.4	0.6	2.8
C9	0.1	0.2	0.4	0.3	0.2	0.2	0.3	1.7
MEAN	0.2	0.5	1.0	0.8	0.6	0.6	0.8	4.5

Table 11. Sterol concentrations (ppm) in pooled epifauna samples taken in each subblock of blocks A, B and C with a benthic sled during February 1980. Levels of 0 indicate value was below 0.1 ppm.

	Sterols							
Station	22-trans-24 Norcholesta 5, 22-dien, 3β-01	22-Dehydro-Cholesterol	Cholesterol	Brassica-Sterol	24-Methyl-Cholesterol	Stigma-Sterol	Sito-sterol	Total
A1	0.0	2530.0	3514.0	1988.0	1084.0	542.1	361.4	10019.5
A2	0.0	128.8	2821.0	85.9	28.6	28.6	28.6	3121.5
A3	0.0	104.8	2567.0	78.6	0.0	0.0	0.0	2750.4
A4	0.0	148.0	2426.0	123.4	61.7	0.0	24.7	2783.8
A5	0.0	143.1	3511.0	125.2	0.0	0.0	0.0	3779.3
A6	0.0	230.0	4477.0	276.3	138.2	46.1	138.2	5306.1
A7	104.9	472.1	9490.0	367.2	314.7	104.9	314.7	11168.5
A8	0.0	86.6	2416.0	61.9	0.0	0.0	0.0	2564.5
A9	0.0	75.1	2466.0	50.1	62.6	0.0	0.0	2653.8
MEAN	11.7	435.4	3743.1	350.7	187.8	80.2	96.4	4905.3
B1	0.0	167.2	4721.0	95.5	0.0	0.0	0.0	4983.7
B2	0.0	144.4	4759.0	120.4	72.2	0.0	0.0	5096.0
B3	53.7	187.9	5319.0	134.2	107.4	0.0	0.0	5802.2
B4	0.0	203.2	6714.0	169.3	135.5	0.0	0.0	7222.0
B5	44.5	178.0	4402.0	155.7	89.0	0.0	0.0	4869.2
B6	0.0	180.0	5938.0	120.0	90.0	0.0	0.0	6328.0
B7	0.0	110.1	3105.0	78.7	62.9	0.0	0.0	3356.7
B8	0.0	155.1	5119.0	103.4	103.4	0.0	0.0	5480.9
B9	0.0	93.5	4639.0	93.5	46.8	0.0	0.0	4872.8
MEAN	10.9	157.7	4968.4	119.0	78.6	0.0	0.0	5334.6

.....cont'd

Table 11 cont'd

Station	Sterols: 22-trans-24 Norcholesta 5, 22-dien, 3β-01	22-Dehydro-Cholesterol	Cholesterol	Brassica-Sterol	24-Methyl-Cholesterol	Stigma-Sterol	Sito-sterol	Total
*C1	48.4	193.5	4785.0	169.3	72.6	0.0	0.0	5268.8
C2	0.0	171.2	6777.0	137.0	68.5	0.0	0.0	7153.7
C3	47.5	166.3	4702.0	118.8	47.5	0.0	0.0	5082.1
C4	0.0	131.4	5208.0	105.1	0.0	0.0	0.0	5444.5
C5	0.0	136.0	3838.0	116.6	58.3	0.0	0.0	4148.9
*C6	59.5	238.2	5888.0	178.6	119.1	0.0	59.5	6483.4
C7	0.0	192.1	6325.0	160.0	96.0	0.0	0.0	6773.1
C8	0.0	76.7	5080.0	51.1	0.0	0.0	0.0	5207.8
C9	0.0	149.2	4207.0	127.9	63.9	0.0	0.0	4598.0
MEAN	17.3	161.6	5201.1	129.4	58.4	0.0	6.6	5567.8

**Trachypenaeus* sp.

Table 12. Sterol concentrations (ppm) in a shrimp (*Trachypenaeus* sp.) trawled from stations in block A, February 1980.

Station	Sterols							Total
	22-trans-24 Narcholesta 5, 22 dien, 3β-01	22-Dehydro-Cholesterol	Cholesterol	Brassica-Sterol	24-Methyl-Cholesterol	Stigma-Sterol	Sito-sterol	
A1	0.0	42.6	4238.0	63.9	0.0	0.0	0.0	4344.5
A2	0.0	99.2	4918.0	73.7	0.0	0.0	0.0	5090.9
A3	0.0	46.9	4642.0	70.4	0.0	0.0	0.0	4759.3
A4	0.0	72.4	4780.0	72.4	0.0	0.0	0.0	4924.8
A5	0.0	50.7	5039.0	50.7	0.0	0.0	0.0	5140.4
A6	0.0	82.3	2314.0	105.8	0.0	0.0	0.0	2502.1
A7	0.0	18.3	3634.0	36.6	0.0	0.0	0.0	3688.9
A8	0.0	44.1	4378.0	44.1	0.0	0.0	0.0	4466.2
A9	0.0	80.5	3994.0	60.4	0.0	0.0	0.0	4134.9
MEAN	0.0	59.7	4215.2	64.2	0.0	0.0	0.0	4339.1

Table 13. Sterol concentrations (ppm) in pooled epifauna samples taken in each subblock of blocks A, B and C with a benthic sled during June 1980. Levels of 0 indicate value was below 0.1 ppm.

Station	Sterols							Total
	22-trans-24 Norcholesta 5, 22-dien, 3β-01	22-Dehydro-Cholesterol	Cholesterol	Brassica-Sterol	24-Methyl-Cholesterol	Stigma-Sterol	Sito-sterol	
A1	0.0	0.2	15.6	0.3	0.0	0.0	0.0	16.1
A2	0.0	0.5	26.7	0.4	0.0	0.0	0.0	27.6
A3	0.0	0.5	10.6	0.3	0.0	0.0	0.0	11.4
A4	0.0	0.5	34.6	0.0	0.0	0.0	0.0	35.1
A5	0.0	0.5	26.4	0.3	0.1	0.0	0.0	27.3
A6	0.0	0.7	34.7	0.7	0.0	0.0	0.0	36.1
A7	0.0	0.6	30.4	0.5	0.2	0.0	0.0	31.7
A8	0.0	0.4	7.1	0.2	0.0	0.0	0.0	7.7
A9	0.0	0.5	31.4	0.5	0.2	0.0	0.0	32.6
MEAN	0.0	0.5	24.2	0.4	0.1	0.0	0.0	25.1
B1	0.0	0.7	32.0	0.3	0.3	0.0	0.0	33.3
B2	0.0	1.2	58.5	0.9	0.6	0.0	0.0	61.2
B3	0.0	0.3	31.5	0.5	0.2	0.0	0.0	32.5
B4	0.0	1.0	28.2	0.7	0.7	0.0	0.3	30.9
B5	0.0	0.6	28.2	0.4	0.3	0.0	0.0	29.5
B6	0.0	1.1	36.2	0.6	0.4	0.0	0.0	38.3
B7	0.0	1.1	42.1	0.6	0.3	0.0	0.0	44.1
B8	0.0	0.8	30.7	0.5	0.2	0.0	0.0	32.2
B9	0.0	0.8	40.2	0.6	0.2	0.0	0.0	41.8
MEAN	0.0	0.8	36.4	0.6	0.4	0.0	0.0	38.2

.....cont'd

Table 13 cont'd

Station	Sterols: 22-trans-24 Norcholesta 5, 22-dien, 3β-01	22-Dehydro-Cholesterol	Cholesterol	Brassica-Sterol	24-Methyl-Cholesterol	Stigma-Sterol	Sito-Sterol	Total
C1	0.0	0.4	37.6	0.4	0.4	0.0	0.0	38.8
C2	0.0	0.5	34.5	0.0	0.2	0.0	0.0	35.2
C3	0.0	0.6	31.2	0.3	0.3	0.0	0.0	32.4
C4	0.0	0.9	42.3	0.4	0.4	0.0	0.0	44.0
C5	0.0	0.6	30.3	0.3	0.3	0.0	0.0	31.5
C6	0.0	0.6	37.3	0.6	0.2	0.0	0.0	38.7
C4	0.0	1.2	59.9	1.2	0.5	0.0	0.0	62.8
C8	0.0	0.5	28.8	0.3	0.1	0.0	0.0	29.7
C9	0.0	0.7	23.8	0.5	0.2	0.0	0.0	25.2
MEAN	0.0	0.7	36.2	0.4	0.3	0.0	0.0	37.6

Table 14. Carotenoid levels (ppm) in sediment samples collected from block A, B and C during February (a) and June (b) 1980.

a) Cruise 2 (February 1980

Station	Level (ppm)	Station	Level (ppm)	Station	Level (ppm)
A1	6.1	B1	1.4	C1	28.8
A2	10.2	B2	9.8	C2	30.8
A3	9.1	B3	38.4	C3	37.0
A4	5.9	B4	61.2	C4	32.8
A5	6.3	B5	46.5	C5	42.8
A6	3.1	B6	7.2	C6	37.3
A7	5.0	B7	12.5	C7	13.2
A8	5.6	B8	15.2	C8	11.6
A9	8.1	B9	39.7	C9	16.9
MEAN	6.6		25.8		27.9

b) Cruise 4 (June 1980)

Station	Level (ppm)	Station	Level (ppm)	Station	Level (ppm)
A1	3.1	B1	5.3	C1	3.9
A2	10.0	B2	2.9	C2	14.5
A3	3.8	B3	10.8	C3	19.3
A4	1.8	B4	1.8	C4	10.2
A5	4.7	B5	17.7	C5	11.6
A6	3.0	B6	2.3	C6	14.9
A7	4.4	B7	12.0	C7	7.8
A8	6.6	B8	6.1	C8	8.1
A9	4.5	B9	11.3	C9	4.5
MEAN	4.7		7.8		10.5

Table 15. Carotenoid levels (ppm) in pooled epifanua samples collected from block A, B and C using a benthic sled during February (a) and June (b) 1980.

a) Cruise 2 (February 1980)

Station	Level (ppm)	Station	Level (ppm)	Station	Level (ppm)
A1	2400	B1	220	C1	313
A2	333	B2	423	C2	279
A3	174	B3	84	C3	180
A4	300	B4	93	C4	53
A5	400	B5	417	C5	54
A6	450	B6	439	C6	536
A7	1440	B7	293	C7	498
A8	293	B8	85	C8	96
A9	222	B9	233	C9	620
MEAN	668		254		292

b) Cruise 4 (June 1980)

Station	Level (ppm)	Station	Level (ppm)	Station	Level (ppm)
A1	59	B1	17	C1	60
A2	51	B2	28	C2	18
A3	28	B3	84	C3	55
A4	85	B4	96	C4	96
A5	92	B5	24	C5	55
A6	36	B6	9	C6	104
A7	83	B7	133	C7	111
A8	39	B8	75	C8	67
A9	112	B9	39	C9	61
MEAN	65		56		70

Table 16. Seasonal and spatial abundance of brown shrimp in block A, B and C, October 1979-September 1980.

Station	Cruise Oct-Nov	Feb	May	Jun	Jul	Aug	Sep	Total
A1	13	4	5	5	165	167	77	436
A2	53	5	28	6	171	63	226	552
A3	108	0	4	4	76	173	108	473
A4	66	7	4	9	15	70	100	271
A5	34	10	5	2	50	115	130	346
A6	43	6	7	3	1	96	112	268
A7	99	8	11	13	11	76	175	393
A8	65	5	9	3	15	72	145	314
A9	39	6	10	9	30	37	40	171
Sub-Total	520	51	83	54	534	869	1,113	3,224
B1	5	0	0	3	24	221	0	253
B2	2	2	2	78	17	317	0	418
B3	1	1	14	263	5	413	0	697
B4	2	1	0	49	29	112	21	214
B5	8	0	0	102	19	339	14	482
B6	4	0	0	79	3	50	3	139
B7	23	2	0	73	15	208	45	366
B8	39	0	0	7	5	8	29	88
B9	43	6	0	105	5	8	29	196
Sub-Total	127	12	16	759	122	1,676	141	2,853
C1	2	5	4	16	19	418	0	464
C2	0	1	2	110	14	599	1	727
C3	2	0	11	75	5	79	4	176
C4	0	2	0	188	14	152	48	404
C5	0	4	2	480	7	188	20	701
C6	0	0	0	266	42	183	49	545
C7	0	2	1	25	4	127	5	164
C8	0	1	0	16	4	469	5	495
C9	0	8	0	38	3	505	4	558
Sub-Total	4	23	20	1,214	117	2,720	136	4,234
TOTALS	651	86	119	2,027	773	5,265	1,390	10,311

Table 17. Seasonal and spatial abundance of white shrimp, October 1979-September 1980.

Station	Cruise Oct-Nov	Feb	May	Jun	Jul	Aug	Sep	Total
A1	-	-	-	-	-	-	-	0
A2	-	-	-	-	-	-	-	0
A3	-	-	-	-	-	-	-	0
A4	-	-	-	-	-	-	-	0
A5	-	-	-	-	-	-	-	0
A6	-	-	-	-	-	-	-	0
A7	-	-	1	-	-	-	-	1
A8	-	-	-	-	-	-	-	0
A9	-	-	-	-	-	-	-	0
Subtotal	0	0	1	0	0	0	0	1
B1	64	202	0	76	28	24	9	403
B2	252	12	18	38	35	17	1	373
B3	201	24	13	42	153	198	58	689
B4	18	3	0	0	0	0	0	21
B5	6	9	0	8	0	0	2	25
B6	4	28	0	0	1	0	4	37
B7	0	3	0	0	0	5	1	9
B8	0	0	0	0	0	5	7	12
B9	0	10	0	0	0	1	10	21
Subtotal	545	291	31	164	217	250	92	1590
C1	80	10	32	0	24	1	0	147
C2	31	9	19	32	27	7	0	125
C3	57	2	18	20	0	3	0	100
C4	5	2	0	0	0	3	4	14
C5	0	4	0	3	0	4	9	20
C6	4	1	0	2	0	1	1	9
C7	0	2	0	0	0	2	1	5
C8	0	2	0	0	0	7	0	9
C9	0	2	0	0	0	5	0	7
Subtotal	177	34	69	57	51	33	15	436
TOTAL	722	325	101	221	268	283	107	2027